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SUMMARIES OF THE RESEARCH SUPPORTED WITH PROJECT GRANT FUNDS BY DIVISION OF RADIOLOGICAL HEALTH

Paul F. Hahn

Public Health Service
Washington, D. C.

4 January 1965

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SUMMARIES OF THE RESEARCH SUPPORTED WITH PROJECT GRANT FUNDS BY THE DIVISION OF RADIOLOGICAL HEALTH

JAN 4 1965

Author : Paul F. Hahn

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
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FOREWORD

The Division of Radiological Health of the Public Health Service is responsible for planning, conducting and coordinating a national program for the evaluation and control of radiation hazards so that the benefits of radiation may be achieved without undue risk. One of the major categories of this national program is the research activities of which the extramural grants program plays an important part.

Research grants allow the utilization of specialized scientific competence available in non-profit organizations and institutions of higher learning. In the Division of Radiological Health a Research Grants Program was instituted shortly after the Division was formed and has held an important position ever since that date.

This compilation has been prepared in order to acquaint scientists in related fields of the types of grants supported under the Research Grants Program and to afford an opportunity for communication between researchers where this is mutually beneficial.

Donald R. Chadwick, M.D.
Chief, Division of Radiological Health

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STATEMENT OF CREDIT

The following abstracts have been contributed by the principal investigators of the projects involved with the understanding that they may be published in the form presented.

No additions, deletions or other editorial changes have been made with the exception of correction of obvious typographical errors.

If further detailed information regarding projects is desired, it is suggested that the investigators be contacted directly.

Paul F. Hahn, Ph.D.
Chief, Research Grants Staff
Division of Radiological Health

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REVIEW OF APPLICATIONS

Applications for Public Health Service research grants are reviewed by study sections or special committees of non-federal consultants expert in their respective scientific and technical fields. These groups were established in order that the advisory councils and committees and the Surgeon General might have the benefit of the best scientific and technical advice on all applications for research grants.

The study section recommendations are submitted to the Advisory Councils or Committees for final review. These latter groups, which are established by Act of Congress, then recommend to the Surgeon General those applications which merit support. The Surgeon General may not approve any research grant that is not favorably recommended by the appropriate council or committee. They also advise on matters relating to programs and activities in their respective areas of research.

In their impartial evaluation of applications, the study sections, committees and councils take into consideration (1) the scientific merit and significance of the project, the competency of the proposed staff in relation to the type of research involved, the feasibility of the project and the likelihood of its producing results, and (2) the adequacy of the applicants' resources available for the project and the amount of grant funds necessary for completion.

The National Advisory Environmental Health Committee serves as the national level advisory body for the Research Grants Staff of the Division of Radiological Health.

PROGRAM AREAS SUPPORTED
BY THE
DIVISION OF RADIOLOGICAL HEALTH
IN ITS
EXTRAMURAL RESEARCH GRANTS PROGRAM

I. Effects of Radiation on Man and Matter

  A. Human Epidemiology Studies

  B. Radiation Physics and Chemistry

  C. Supportive Radiobiological Studies

    1. Genetic Radiation Damage

    2. Somatic Radiation Damage

    3. Aging Due to Radiation Damage

    4. Radiation Damage Mechanisms

    5. Modification of Effects

II. Measurement of Radiation Exposure

  A. Methodology and Instrumentation

  B. Population Exposure

III. Development of Methodology for Exposure Reduction and Control

  A. Studies of Environmental Pathways

  B. Studies of Protective Action in Environmental Contamination

  C. X-ray Exposure and Radionuclides

IV. Others

  A. Radiation Meetings and Conferences

  B. Non-Ionizing Radiation

  C. Beneficial Applications

I. EFFECTS OF RADIATION ON MAN AND MATTER

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RH 00002
RAD

"ELECTRON MICROSCOPY OF SINGLE CELLS IRRADIATED BY A MICROBEAM OF α-PARTICLES"

A method for microbeam irradiation of cells grown in tissue culture with subsequent examination of a particular cell in the electron microscope was developed.

The collimated source, Polonium -210 sealed in a perspex capsule, was mounted on a long working distance condenser of a phase contrast microscope. The capsule was so designed that its diameter was less than the ring of light formed by the substage annulus. For normal observation, the source was within the cone of light illuminating the specimen, and therefore did not interfere with pre- and postirradiation observation. It was only during the irradiation itself, a matter of seconds when the condenser was raised to bring the source in contact with the coverslip on which the cell was growing that the cell was not visible for observation.

Liquid hanging drop chick heart fibroblast cultures were used. The cultures were grown on very thin plastic (Melinex) coverslips fixed onto depression slides. For irradiation, the explant was removed and the coverslip on which the proliferating outgrowth remained was transferred to an extremely thin stainless steel chamber. The Melinex film formed the bottom coverslip. As all observations were made through the chamber the thin chamber was essential for high magnification work.

After irradiation, the cultures were immersed in cold buffered OsO_4 and dehydrated in a series of alcohols prior to embedding in Araldite for the electron microscopy.

It was found that Araldite did not adhere to "Melinex". Upon trimming a block in which a "Melinex" coverslip had been embedded the block would split apart at the surface of the "Melinex" and the plastic would peel off leaving the cells of the culture clearly visible on the surface of the Araldite. With the aid of a dissecting microscope the irradiated cell could be identified, a small block could then be cut with the cell at a known orientation to the block faces. A small microscope was devised to be used in conjunction with the Huxley ultramicrotome which made it possible to observe the cells in the block during the thin sectioning. In this way it was known when a particular cell or group of cells was being cut, and those sections were examined in the electron microscope.

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Areas of the cytoplasma of cells were irradiated in this manner to investigate how ionizing particles damaged the fine structure of a cell and if there was any localization of damage. It was found that the mitochonria, endoplasmic reticulum, ribosomes, in fact all cytoplasmic inclusions were severely damaged by small numbers of a-particles passing through a strictly localized region of the cytoplasm. The same type of damage was visible throughout the entire cytoplasmic area with the possible exception of the formation of large multi-membraneous bodies near the particle path. When a cell was irradiated with small doses of alpha-particles (order of 10) much of the cells fine structure was perfectly normal in appearance, however, badly damaged, abnormal structures were present throughout as well. The distribution of damage seemed quite random. No damage to the nucleus was apparent although the method of fixation chosen was not one that would show nuclear structure in any detail.

***

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RH 00004
RAD

"EFFECTS OF DIFFERENTIAL X-RAY ABSORPTION BY BONE AND SOFT TISSUE"

The effects of whole body x-radiation on growth, density, and chemical composition of the skeleton of the male albino rat was studied as influenced: (a) by the relative quantities of energy absorbed by bone and soft tissue; (b) by fractionation of the dose; and (c) by the age of the animal.

Method: In studying (a) above, three groups of 30-day-old animals (Groups I, II, III) were administered absorbed doses of x-radiation expressed in rads as follows: Group I, 732 rads bone, 576 rads soft tissue; Group II, 732 rads bone, 256 rads soft tissue; Group III, 1649 rads bone, 576 rads soft tissue. Fractionation was studied by administering the total dosage given Group I to Group IV (30-day-old animals) in 6 equal daily doses, and to Group V in 6 equal weekly doses. The dosage given Group I was also administered in a single exposure to Group VI (animals 90 days of age) and to Group VII (animals one year of age).

The more direct effects of radiation on bone were studied by administering 2500 rads to the right tibias of rats (Group VIII, animals 26 days old) otherwise protected by lead shielding.

Results: Approximately 50% of the irradiated animals in Groups I and III died during the 30-day period following exposure. Similar figures in the other groups were: II, 1%; IV, 10%; V, 0%; VII, 20%; and VIII, 0%. The animals of Groups I and III which survived restricted their food intake approximately 50% during the two-week period following irradiation. The body weights of these animals and of their pair-fed controls were 25% less than those of their ad libitum-fed controls one month following radiation.

Food restriction persisted in Group III through one year of age and they reached only 80% of normal weights within this time. The body weights of Group II were 90% of normal at one year of age. Substantial but lesser amounts of food restriction also were noted in Groups IV and VII.

Whole-body radiation adversely affected the skeleton as indicated (a) by reduced elongation of the Tibia, (b) by decreased skeletal weights, (c) by reduced bone density as measured in the proximal ossific center and the shaft of the tibia, and (d) by elevated fat content of the dry femur. These changes were most marked in Group III, followed by those in Groups I, IV, V, VI and VII, in this order.

In both soft tissue and skeletal growth aspects, the pair-fed controls tended to resemble their irradiated pairs more than the ad libitum-fed partners during the early months following irradiation, indicating the importance of food restriction on the magnitude of the adverse changes observed in the irradiated rats. As the food restriction imposed on the pair-fed rat was lifted as the length of time following radiation increased, the pair-fed rats became increasingly similar to the ad libitum-fed controls, while the irradiated rat still exhibited the residual effects of radiation in spite of increased food consumption.

Skeletal maturation was accelerated by radiation when this was not accompanied by marked curtailment of food intake, but it was retarded when the latter resulted from the radiation exposure. Thus, skeletal maturation was accelerated in the irradiated rats of Groups II, IV, V and VI, but retarded in Groups I and III.

Tibias receiving localized radiation (Group VIII) exhibited severe retardation growth, decreased water content, but an increase in bone density and ash. The percent of calcium or phosphorus in the ash of the irradiated and of the nonirradiated tibias did not differ.

***

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RH 00005
RAD

"RADIATION EFFECTS ON FORMATION OF PROTEIN AGGREGATES"

This study is concerned in general with the effects of radiation in vitro on the interaction of proteins, and more specifically with the radiation-induced alterations in the reactions between antigens and antibodies. The system being studied at present is beef insulin and its rabbit serum antibody.

Insulin forms a nonprecipitating antigen-antibody complex with rabbit antiserum. The advantage of using a system with a protein of known structure (insulin) was somewhat tempered by the necessity for developing a method for measuring small changes in concentration of antibodies without the benefit of precipitin analysis. A method which will detect small changes in antibody concentration has been found and reported (Haymond and Arquilla, Eighth Annual Meeting of the Biophysical Society). The method involves incubation of a dilute solution of rabbit antiserum with radioactivity-labeled insulin and subsequent separation of the antigen-antibody complex from the free antigen by adsorption of the free antigen or an anion exchange resin. With this method it has been possible to work with dilute aqueous solutions of antiserum and insulin. (Insulin concentrations of 10^{-10}M have been used). Rabbit antiserum taken from one animal at one time has been used in a series of radiation experiments in order to minimize effects due to heterogeneity of the antiserum.

The principal radiation source used to date has been 300 KVP X-ray, HVL 2 mm. Cu. Just recently work has been started with a cobalt-60 irradiation unit. Exposure dose has been determined with ionization chambers and absorbed dose determined with ferrous sulfate dosimetry.

When dilute, air-saturated, aqueous solutions (1% or less) of rabbit antisera are irradiated, changes in active antibody concentration can be detected with doses as low as 3000 rads (1.8×10^{17} e.v./ml.) by use of the assay method referred to above. Dose-response curves indicate a D37 of 1.7×10^{18} e.v./ml. for a 1:100 solution of antiserum in 0.09% saline (phosphate buffered, pH 7.4). The D37 is a function of salt concentration and concentration of antiserum. The salt concentration effect could be due to competition between the salt and the antibodies for reaction with the free radicals produced in water by radiation or there could be an effect, due to salt concentration, on the configuration of the protein which might alter its radiation sensitivity. Both possibilities are under consideration.

The present system seems to offer considerable promise for obtaining information about indirect radiation effects on protein-protein interactions. Present studies are directed toward determining the relative importance of the presence of salts, other proteins and other solutes, including oxygen, in the process of radiation-induced alterations of antibodies in aqueous solution.

***

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RH 00008
BBC

"STUDIES OF RADIATION DAMGE TO BIOLOGICAL MATERIALS"

The principal objective of this research is the experimental investigation of the effects of high energy radiation in producing permanent damage to molecules. Electron spin resonance spectroscopy is employed to detect and identify trapped radical fragments produced in biologically significant crystalline compounds. In addition there are also revealed certain details of crystal structures and molecular orientations. Examination of materials which have been exposed to damaging radiation indicates the tolerance or immunity of these materials to high energy radiation, and in some instances, also indicates the mode of recovery of the systems from this damage. However, in other damaged systems, radicals have been observed to be stably trapped for at least two years.

The compounds which are examined are selected for their importance in biological systems and for chemical and physical characteristics whose existence may influence the effects of radiation. For example, the amino acids have proved especially interesting for these reasons. Single crystals of closely related chemical compounds are grown and subjected to massive doses of radiation (10^5 r or more). Ultra-violet, x-, and γ-rays are employed to produce this damage. The damaged crystals are examined in an electron spin resonace spectrometer which is capable of detecting the presence of approximately 10^{14} trapped radicals. In the crystals used this represents approximately one damaged molecule in 10^3 to 10^6 undamaged molecules. By recording spectra for several crystal orientations in the magnetic field of the spectrometer, it is possible to identify the radical fragment which has been stably trapped in the crystal lattice. The structure of this fragment is also revealed by these orientation studies.

For pusposes of confirming interpretation of spectra it is common to employ isotopically substituted compounds. For this reason, crystals grown by evaporation from aqueous solution are also prepared from solutions in D_2O, in order that certain hydrogen atoms in the molecule may be replaced by deuterium atoms.

In some instances the resulting spectra indicate that two or more identical radical species are present in the crystal in different orientations. Such magnetically inequivalent species may be readily identified. In other instances, however, there appear to exist two or more chemically different radicals. In this case, it has proved useful to employ thermal bleaching to distinguish between the two systems. To do this the damaged crystal is heated to a temperature at which one of the radical species is eliminated, thereby simplifying the interpretation of the remaining spectrum.

Temperature influences the type of radical produced as well as the character of the spectra of a given radical. Irradiation at different temperatures in some instances causes different damage. Also, it has been observed that a given crystal may show different spectra depending upon the temperature at which the spectra are taken. This effect is interpreted as arising from the rotations of the molecular groups within the radicals. At lower temperatures, rotation becomes hindered, changing the appearance of the spectra.

Through this research it becomes possible to determine an ordering of the probability of damage, according to the molecular sub-groups contained in the compounds examined. Certain portions of molecules show surprising immunity to radiation, whereas other groups are characteristically susceptible to damage.

***

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RH 00014
RAD

"BIOCHEMICAL STUDIES ON ENDOCRINE SYSTEM UNDER RADIATION"

Twenty-four hours after a single whole-body X-irradiation (400 r), a significant decrease was observed in Zn-65 uptake of testes in mice. Similar depressing effects of X-irradiation on the testicular Zn-65 uptake was found after a single localized irradiation (1,000 R) on the scrotum and hind-legs. Local irradiation on the head and fore-legs had less but signficantly depressing influence on testicular zinc uptake.

On the steroidogenesis of testis _in vitro_, it was found that X-irradiated testes after one month produced androgens following the same biogenetic pathway from progesterone as in intact testis, but quantitatively, the amounts of polar steroid production was inhibited by the radiation. Besides this, on the biotransformation of progesterone-C^{14} with testicular cell suspension _in vitro_, several newly isolated steroids from the organs were identified as 16α-hydroxyprogesterone, 6β-hydroxyprogesterone, 20α- and 20β-hydroxpregn-4-en-3-one, 17α, 20α-dihydroxypregn-4-en-3-one, etc.

***

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RH 00021
RAD

"THE EFFECTS OF X-IRRADIATION ON THE SMALL INTESTINE"

The studies have been concerned with X-irradiation of the small bowel of rats under different conditions and the assessment of the subsequent damage and physiological status of the intestine after irradiation.

β-mercaptoethylamine (MEA) given prior to X-irradiation or mesenteric vessel clamping during X-irradiation of the exteriorized ileum and jejunum in rats reduced mortality, body weight loss in survivors, and histological damage compared to that found in irradiated controls. MEA and vessel clamping were not effective with X-ray exposures of 2200r and above and 3000r and above respectively. The combination of the two treatments resulted in 67% survival at the exposure of 3500r where neither treatment by itself was effective, but became completely ineffective at 4500r and above.

When animals which received 1800r and MEA were compared on a mortality and histopathological basis with those exposed to 1400r with no drug treatment, the responses were very similar. It was then decided to determine whether the ability of the small bowel to absorb iron or fatty acid was impaired in intestine-irradiated rats receiving 1400r, 1800r alone, or 1300r alone, or 1800r preceded by MEA (100 mg/kg I.P.).

In order to study the mucosal uptake of iron by the small intestine, a perfusion technique was used. All but 6 cm. of the ileum and jejunum was perfused with $Fe^{59}SO_4$ solution (pH6) at 1, 3, 6, 12, and 20 days after exposure. The decreases in nucosal uptake of Fe^{59} were similar in all categories for the first three days. The mucosal uptake after MEA and 1800r was much higher at all times after day 3 than in animals given 1400r alone, but on a histological basis, the intestines of both irradiated groups were similar throughout a 20-day period after irradiation. Thus, there is a difference between the rate of histological and physiological recovery in the two groups.

Attempts to obtain quantitative data on fatty acid absorption have not yet been fruitful. The perfusion technique was tried but later abandoned because during a one-hour perfusion very little absorption occurs. Using another approach, we have attempted, after oral administration of I-131 oleic acid, to relate the amounts of radioactivity in segments of the intestine to each other and to the activity remaining in the carcass. The results are inconclusive thus far.

As a by-product of the Fe^{59} perfusion study in intestine-irradiated rats, the effect of pH on mucosal uptake of Fe^{59} was studied in normal, mesenteric vessel-clamped, and MEA-injected rats. Mucosal uptake of Fe^{59} was below normal when MEA was given intraperitoneally 15 minutes before perfusion. The clamping of the mesenteric vessels during the entire period of perfusion reduced mucosal uptake even more than did MEA. Activity of Fe^{59} in the blood of the clamped group was twice the normal value. Consistent blood values weren't obtained in the MEA group. Mucosal retention of Fe^{59} was much higher ar pH 4 than at pH 2 and pH 6, but blood activity was considerable higher at pH 2 than at pH 4 and pH 6.

Experiments are in progress to establish the nature of the very early changes in a radiation-induced intestinal lesion which has been classified as an adenocarcinoma (Radiation Research 18, 76-83(1963)). None have yet been very helpful. In other tumor experiments, procedures of X-ray dose fractionation have been employed in attempts to make the tumor more invasive. The results are inconclusive as yet.

***

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RH 00024
RAD

"EFFECT OF X-RAY ON HUMAN CHROMOSOMES"

The research project centers about the effect of different modalities of radiation on human chromosomes. In the first phase of the investigation the effect of radiation on changes in sex chromatin was studied. Normal patients receiving X-ray therapy, as well as patients with malignancies and cutaneous viral infections (warts and herpes) were investigated. Malignancies and viral infections were selected because of type of nuclear change associated. The studies showed that if cytologic preparations from buccal and vaginal mucosa were technically good and the nuclear disturbances not too severe, it is possible to observe sex chromatin, and without change in frequency, in all conditions investigated. With Feulgen staining of thin sections, sex chromatin may also be observed in skin.

The next series of studies in cytogenics was the exposure of cultures of monocytes from peripheral blood to X-ray, Grenz ray and laser radiation. The radiations used included X-ray irradiation of HVL 0.9 mm. Al , 600 r; 1800 r of Grenz HVL 0.033 mm. Al and various types of laser radiation. Because of the character of Grenz rays it is difficult to be certain of uniform exposure and special exposure chambers were developed for the experiments. Initial studies indicate that little, if any changes result from Grenz ray. In conrast, X-ray of HVL 0.9 mm. Al. induces significant chromosomal aberrations including rings, dicentrics and deletions. It is difficult also to be certain of uniform exposure of the cultures of white cells with laser rays, but preliminary studies indicate no chromosomal aberrations are found even with high-energy laser beam impacts.

In addition, patients who had received therapeutic radiation with conventional X-ray and Grenz radiation for dermatological disorders were examined for possible chromosomal aberration with cultures of their peripheral white cells. There is no indication of increased abnormalities in chromosomes brought about by therapeutic superficial radiation of the quality of HVL 0.9 mm Al to localized areas. Tissue cultures of skin from biopsy sites that have been exposed to the same type radaition have also been examined. Here, too, no chromosomal changes were observed. These experiments are currently being confirmed with a larger series. Much additional data is needed before chromosomal aberrations can be used as a biologic test for therapeutic X-ray radiation of the superficial types.

***

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"AUTOLOGOUS BONE MARROW PROTECTION AS AN AID TO CHEMOTHERAPY"

Autologous, isologous and homologous bone marrow protected against lethal doses of X-ray radiation, nitrogen mustard and chlorambucil in rodents, dogs and monkeys. Autologous or isologous bone marrow protection was superior to homologous marrow protection concerning long time survival. The decrease in circulating blood cells following these procedures was indistinguishable in bone marrow protected and control monkeys. However, in bone marrow protected animals the presence of leukocytes could be demonstrated in tissues particularly after challenge with irritant oils injected into granuloma pouches. Injection of bacterial lipopolysaccharides caused leukocytosis in bone marrow protected, but not in control monkeys. This method was found to predict whether individual monkeys are going to survive or not. In rodents protected with homologous bone marrow, secondary disease developed regularly. The number of animals which escaped appeared to depend on the strain and sex combination used. In monkeys secondary disease was rare. The reason for this difference was thought to be the fact that (1) the bone marrow of rodents is richer in immunologically competent lymphoid elements than that of the monkey, (2) there is a delay in regeneration of lymphoid elements as compared to other hemic cells in the monkey. (3) the monkeys used might have originated from an area in their native habitat where "close-breeding" has occurred under natural conditions. These and other factors are currently being investigated. A small but significant decrease in occurrence of late disease was observed in mice when the homologous bone marrow donor was treated with cortisone, nitrogen mustard or both. Pretreatment resulted in decrease of small lymphocytes in the marrow and presumably decreased graft takes against host reactions. None of the rodent tumors investigated, could be eradicated with radiation or chemotherapy and bone marrow protection. Radiation dose tolerated by the host could be further increased by perfusing the intestines with aminoethylisothiuronium during radiation. Combination of this procedure with bone marrow transplantation allowed survival of mice at doses of radiation against which either procedure failed to protect. We have obtained a number of new alkylating agents which were remarkable in their low gastrointestinal toxicity. Increase in therapeutic index was noticed when high doses of these drugs were

RH 00026 (continued)

followed by isologous or autologous bone marrow transplantation. Another series of drugs showed radiation potentiating effect in animal experiments and a limited clinical trial in inoperable bronchogenic carcinoma.

Animal experiments are in progress on the use of bone marrow transplantation in connection with this agent and radiation. In a series of experiments using various immunologic markers in monkeys, homologous marrow transplantation was shown to produce only temporary takes with eventual reversion to the original type. Documented secondary disease occurred during the period of reversion. Attempts are now being made to produce permanent marrow takes.

***

RH 00034
GEN

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"EFFECT OF RADIATION-INDUCED MUTATIONS ON FITNESS"

1. Effects on several components of fitness (Hiraizumi): Several males of D. melanogaster (+/cn L² bw) were X-rayed (100 r/min. for 3 minutes [illegible] stage) in order to find out whether flies heterozygous for [illegible] induced mutations on second chromosome show any demonstrable increase in fitness. All the + second chromosomes used in this study were originated from a single chromosome, and the genetic background other than that of the second chromosome had been replaced by that of the standard stock. About 160 X-rayed and the same number of control chromosomes were tested for their effects on female fertility (no. of F_1s produced in the first 9 days), developmental rate (measured by the period from egg till eclosion in comparison with a standard stock) and larval stage viability. The results are summarized as follows (+' = X-rayed chromosome). 1. Female fertility: +'/+ showed significant and +'/+' showed highly significant reductions in female fertility. 2. Rate of development: +'/+ showed significantly faster, and +'/+' slower (not significantly) developmental rate. 3. Larval stage viability: +'/+ showed increased and +'/+' decreased viabilities (both not significantly). This experiment is still continuing for conclusive results.

2. Further tests for viability (Mukai): Heterozygous effects of mutations induced by 500 r X-rays (acute, sperm) were conducted in one homozygous (intra and inter-populational hybrids) genetic backgrounds. The results indicate that radiation-induced mutations which occurred in homozygous individuals were heterozygously beneficial while those in heterozygous genetic backgrounds did not manifest their effects significantly.

RH 00034 (continued)

3. Estimation of spontaneous mutation rate of poly-genes controlling viability (Mukai): A single male Pm/+ from the cross Cy/Pm x +/+ (an isogenic stock) was sampled and multiplied by the cross Cy/Pm (♀♀) x Pm/+ (♂), and 104 lines of Cy/Pm x Pm/+i (i=1,2,...., 104) were established. In each line, the second chromosome has been maintained through a single male by the cross Cy/Pm (5♀♀) x Pm/+i (1♂). In generations 10, 15, 20, 25, 32, and 52, homozygous viabilities of these chromosome lines were tested. Using the increment of genetic variance among the viabilities of these lines and decrement of mean viability, spontaneous mutation rate of the polygenes in question was estimated to be at least 0.13/second chromosome/generation. In addition to the estimation of homozygote viabilities, the dominance degree of these mutant polygenes were estimated in various genetic backgrounds. The results indicate that newly arising mutant polygenes are overdominant in homozygous genetic background at least when those genes are located only in one chromosome, while heterozygously detrimental in heterozygous genetic backgrounds.

***

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RH 00035
GEN

"RADIATION EFFECTS IN EUPLOID HUMAN CELL CULTURES"

We have studied two general areas of X-ray-induced effects in adapted human cell lines; anaphase abnormalities and cell population size distributions.

A. In the studies of anaphase abnormalities the work on multipolar divisions is most nearly complete. The frequency of multipolar anaphases in the KB human cell line were found to be .038 + .007 when studied over a period of 14 months. Multipolarity was about evenly divided between tripolar divisions and tetrapolar divisions with a much smaller frequency of cells observed with greater polarity.

Irradiation with 250 KV X-rays increased the frequency of multipolarity observed. A high positive linear correlation was found between the maximum frequency of induced multipolarity and radiation dose. About 400 r would produce 50% multipolarity and 100% multipolar divisions would theoretically result from 800 r. If the "survival curve" (dipolar cells) is considered an exponential function of radiation dose, then the mean lethal dose would be about 590 r. These data indicate that radiation induced multipolarity is the result of damage to a sensitive volume (target). The dose required to double the

RH 00035 (continued)

background frequency of multipolarity suggests this primary target has approximately the same sensitivity - (or size according to the target theory of Lea) - gene mutations. A single or functionally double centriole does not appear to satisfy the requirements for the target, because there was neither a sequential appearance of tripolar and tetrapolar spindles after irradiation nor was there a differential frequency of occurrence between the two kinds of multipolarity.

B. In the studies of cell population size distribution at various times after irradiation. This work is still in progress.

***

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RH 00039
PTHB

"RESEARCH ON THE EFFECT OF THOROTRAST"

This is an epidemiological study on the effects of thorotrast (colloidal thorium dioxide) which was used in many countries as a radiological contrast medium. It was employed principally in cerebral angiography, in arteriography, and phlebography. In Portugal, thorium was widely used because of the great development of angiographic studies in 1931. There have been reported cases of death due to the use of this substance from diseases of the bone marrow, leukemias, malignant tumors, cirrhosis, and "thorotrast granuloma".

The present research has been to determine: 1) the number of individuals injected by thorotrast; 2) the number of individuals alive with or without clinical symptoms due to thorotrast; 3) the number of individuals who died with a disease induced by thorotrast; 4) the number of injected individuals whose address is unknown.

This work includes: 1) a patient questionnaire and examination; 2) a questionnaire to the families of dead patients; 3) a medical assistant questionnaire; 4) an examination of the records of private and public official hospitals as well as doctors; 5) examination of the death records in the National Archives.

Previously, the work had been limited to Lisbon, but it has now been expanded to include all of Portugal. At the present there are 1500 cases in the study. This is considered a potentially very valuable study, not only of the effects of the specific contrast agent, but of the continued effects of low level radiation in man. It covers a time period from 1930 to 1950. They have already found 47 cases of granuloma.

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RH 00047
RAD

"OCCUPATIONAL LUNG CANCER FROM IONIZING RADIATION"

This laboratory has been involved in a series of studies on mechanisms of pulmonary carcinogenesis utilizing ionizing radiation. Techniques have been devised for the evaluation of dose response effects, the investigation of the effects of variations in dose rate, and the examination of the serial stages in the morphogenesis of bronchogenic cancer.

Groups of rats were exposed to beta radiation derived from Ru^{106} plated pellets implanted within the bronchi. Microcurie levels varied from 0.008 to 13.6 and integrated dose from 10^3 to 10^6 rads. Since the spatial relationships of the emitting pellet to the bronchial origin of tumor was known, dose to the specific target tissue could be directly calculated. This is in contrast to previous quantitations of radiation to the bronchus in terms of "average lung dose". Sixty-eight animals with squamous cell carcinomas were observed among the 265 rats exposed. The tumors occurred in dose related fashion with incidence progressing from 7.3% in animals exposed to 10^3 rads to 65.6% in those exposed to 10^6 rads.

Studies of the role of the time pattern of radiation delivery in the production of lung cancer began with the use of varying levels of Ru^{106} plated on pellets. A hollow plastic pellet has been devised for the examination of dose rate effects on tumor induction with the use of isotopes of varying half life. Experiments involving doses of 10^4 and 10^5 rads delivered by varying quantities of P^{32} and Ru^{106} have resulted in fairly comparable tumor yields at each dose level. Thus within the time limits of delivery of these doses by these materials, (29 days to 300 days) the tumor yield has been independent of dose.

Serial sacrifice experiments utilizing groups of rats exposed to 5 microcuries of Ru^{106} plated on an intrabronchial pellet has permitted an examination of the sequential changes that precede the development of invasive tumor. These studies have revealed a consistent pattern of change ranging from hyperplasia to squamous metaplasia, to atypical basal proliferation, to invasive cancer.

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RH 00061
ESE

"IMPROVEMENT IN SANITATION BY IONIZING RADIATIONS"

The study is concerned with an evaluation of certain factors which contribute toward microbial radioresistivity. The main emphasis in the past had been directed toward investigating compounds which would decrease radiation survival. These radiosensitizing compounds were inorganic compounds such as sodium and potassium chloride or sulfhydryl reagents such as the naphthoquinones. Both classes of compounds enhance the lethal effects of radiation by different mechanisms. The chlorides decrease radiation survival during irradiation and, in addition, exert a lethal post-irradiation activity. For the post-irradiation effect to be noted, organic material had to be eliminated, and oxygen present.

In contrast, the radiosensitizing effects of naphthoquinones (menadione, 1,4 naphthoquinone and 1,2 naphthoquinone) were more pronounced when conducted in a nitrogen atmosphere. The presence of proteins and sulfhydryl groups inhibited or eliminated the effectiveness of these compounds. Experiments to distinguish between whether or not these compounds actually enter the cell or exert their influence in the vicinity of the cell are to be conducted shortly. Washing experiments to date indicate one of two possibilities since cells exposed to naphthoquinones and then washed prior to irradiation were not radiosensitized. The possibilities are that these compounds might have entered the cell and then have been subsequently washed out of the cell, or that the free naphthoquinones in the menstruum are mainly responsible for radiosensitization.

Experiments utilizing radioactive tracers will be conducted in the near future. The necessity for using tracer experiments is an outgrowth of thermal resistivity experiments in the presence of naphthoquinone. The naphthoquinones have been found to also be effective heat sensitizers but, in contrast to the effects noted with irradiation, washed cells displayed a residual effect in that they were still thermally sensitized, although to a lesser extent than when the sensitizer is present.

Naphthoquinones differ in a number of respects in their radiation and thermal sensitizing activities from other sulfhydryl compounds, and the possibility exists that sulfhydryl-binding activity may only be one of the mechanisms involved in radiosensitization.

Although effective in buffer solution against vegetative cells of moderate radioresistivity, the naphthoquinones are much less effective or are ineffective in the presence of food materials. This statement also holds for spores, a wild yeast, and Micrococcus radiodurans.

Recently, a red-pigmented, radiation-resistant coccus distinct from Micrococcus radiodurans was isolated and characterized. The DNA content has been shown to be within the normal range for bacteria.

This organism is being employed for studying synergism between ultraviolet and gamma radiations as reflected in damge to DNA. These experiments are still in progress.

Future emphasis will be placed on examining the effects of recovery mechanisms on radiation repair in natural foodstuffs and in model systems. Preliminary studies have indicated that cell leakage is an important factor and may be a reflection of the extent of damage and therefore a measure of the extent of synthesis required for repair.

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RH 00063
AI

"POTENTIATION OF ANTIGENS BY GAMMA-RAY IRRADIATIONS"

A variety of proteins of widely differing molecular weights were irradiated and studied for modifications in their physiochemical and immunobiological properties. Currently, the in vitro production of antibodies, using radiation-altered serologically inactive gamma globulins as "substrates", is being attempted. Radioactive methyl green is being synthesized to use as a label for measuring the molecular correspondences of radiation altered DNA's and RNA's.

Each protein that was studied was first irradiated over a range of dosages to establish serologically its G value and to determine the characteristics (exponential vs. sigmoid) of its inactivation curve. Solutions and lyophilized samples of each kind of protein are irradiated. Thus far, lysozyme, ovalbumin, bovine gamma globulin and several hemocyanins (solutions only of the latter) have been studied. The environments of the proteins, during irradiations, were modified using inorganic and chemical additives to serve as "scavengers", or oxidizing or reducing agents.

For the lyophilized proteins the X-ray dosages have ranged from 10.0 to 300 electron volts per molecule (ev/mol). For solutions (usually 1%) the doses of irradiation have ranged between 100,000 and 2.0×10^6 roentgens.

Irradiated samples of lyophilized protein, after being placed in solution, contained amounts of radiation-denatured, isoelectrically insoluble protein (D) that are directly related to the absorbed dose. Characteristically, there is a post irradiation development denatured thermolabile protein (L). The rate at which L develops is a direct function of the temperature, between 5° and 40° C, at which the protein solutions are stored or heated. For any given dose the amount of total yield of L is characteristic regardless of the rate at which it forms.

Lyophilized ovalbumin (OA) and human gamma globulin (HGG) lose their serological activity exponentially at a similar rate over the same range of irradiation dosages (30 to 175 ev/mol). Inactivation of 1% solutions of OA and HGG requires higher absorbed dosages and the rate of loss is inversely related to molecular size. The serological inactivation of irradiated solutions of hemocyanins is also inversely related to molecular size. Solutions of OA have an inactivation curve that is exponentially related to dose. The inactivation curves become increasingly sigmoid as the molecular weights of the proteins increase. Native and γ-irradiated preparations of lyophilized OA have identical migration rates in a moving boundary electrophoretic field and otherwise are similar. Paper-strip electrophoretic analyses, however, reveal a wide spectrum of modified molecules in the irradiated systems. The survival of electrophoretically native OA in lyophilized preparations and in solutions is exponentially related to irradiation dose. Irradiation of lyophilized OA induces the formation of polymers. Low temperature fractionation of the system supplements the tendency toward polymerization and increases the size of the polymers. Sedimentation studies on irradiated solutions of OA, HGG and hemocyanins reveal only minor changes from native preparations. Overall sedimentation rates are not changed. A reduction in the number of components in the hemocyanins is interpreted as evidence for some polymerization in these systems.

Irradiation of lyophilized HGG results in the production of aggregates that are separable from normal globulin by the use of Sephadex G200 or 0.62 M Na_2SO_4. Heating of native HGG at 55° results in the production of aggregates that possess properties similar to irradiation-aggregated HGG and exhibit sedimentation rates in the ultracentrifuge ranging from 17S to 58S. Aggregation is not inhibited by 4 M guanidine hydrochloride nor by 0.02 M iodoacetate. The irradiation-aggregated HGG combines specifically with anti-native HGG antiserum, and the serological activities of irradiated samples are dependent upon the specificity of the antiserum; and inactivation dose of 38 electron volts/molecule (ev/mol) was obtained using an early antiserum whereas an inactivation dose of 250 ev/mol was obtained using a late, hyperimmune antiserum.

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RH 00064
RAD

"INVESTIGATIONS ON A RADIATION RESISTANT MICROORGANISM"

During studies on the effect of gamma radiation on the sterilization of food products, a bacterial species (tentative nomenclature: Micrococcus radiodurans) was isolated from meat which had been exposed to dosages of $2x10^6$ and $3x10^6$ rad. The presence of the radiation resistant microorganism was subsequently confirmed by culturing the organism in various liquid and solid media and then irradiating them at two radiation sites which included cobalt 60 and atomic fission by-products. Exposure to various dosages demonstrated that this microorganism, a non-sporeforming, pink-pigmented tetracoccus, survives $4x10^6$rads in ground meat or tryptone glucose yeast extract broth (TGY) and up to $5x10^6$ rad on TGY agar slants (1, 3, 7, 8, 9). The LD_{50} for gamma rays was approximately $8x10^5$ rad depending upon the age of the culture and the substrate in which it was irradiated (7, 8, 9). Subsequent exposure to ultraviolet and electron rays showed them to be extremely resistant to this type of irradiation also.

A chemically defined medium found to support growth consisted of methionine as the only essential amino acid in combination with glucose, two vitamins and essential minerals (2, 16). The incorporation of L-glutamic acid stimulated growth (16). It was also observed that cyanocobalamine (vitamin B_{12}) could replace methionine provided an inorganic source of sulfar was present in the medium (16).

The metabolism was studied by manometric and radiotracer techniques. Methionine the only required amino acid appeared to be rapidly incorporated into the cells. DL-glutamic acid is readily metabolized, the D isomer apparently after an initial lag. Among the simple carbohydrates fructose, glucose, and glycerol are rapidly utilized. The operation of the tricarboxylic acid cycle (TCA) is suggested by the oxidation of certain TCA intermediates. The prompt conversion of C-1 of glutamate to CO_2, in the presence of glucose, may suggest that A C -C5 cleavage pathway is operative for catabolism of glucose (2, 4, 6). Taxonomically the organism is different from similar species in its fermentation reactions and markedly so in its extreme radiation resistance (12, 15). It has been observed that it has a rather unusual cell wall structure and based on this cytological difference it has been suggested that it be given a new generic designation (18).

Investigation of the factors which could influence irradiation resistance have revealed six different carotinoid pigments which could account in part for its unusual tolerance to ultraviolet light (3, 14). The pigments were recovered as the non-saponifiable fraction from the solvent soluble lipid material extracted from the cells, This fraction appeared to be an integral part of a complex cell wall. Hydrolysis of the cells and solvent extractable lipids showed a preponderance of unsaturated C_{12}, C_{14}, C_{16}, and C_{18} fatty acids, with C_{16} being the most abundant as well as the corresponding unsaturated fatty acids. The C_{13}, C_{15}, and C_{17}, fatty acids were also observed in trace amounts (20).

The lipid-proteins were not investigated. However, an interesting new mucopeptide has been isolated from the cell wall structure (19), as well as a different phospholipid, both of which are being investigated at the present time (20).

The role of the pigments and the unsaturated fatty acid in irradiation protection is not understood. However, it is conceivable that they could act as free radical acceptors or in the case of the pigments serve to absorb ultraviolet light (10, 11, 14, 17).

During our investigations of the metabolism it was observed that the end products of respiration consisted of several sulfur-containing compounds, one of which was hydrogen sulfide and the other a mercaptoalkylamine. The latter series of compounds have been extensively used as irradiation protectants in experiments with mice subject to gamma irradiation. These compounds have also been shown to protect bacteria (16).

When a solvent-extractable material from the cells is injected intraperitoneally into mice in a suitable preparation, it can be demonstrated to have a protective action when administered immediately before irradiation and a therapeutic effect up to 24 hours when administered following exposure to irradiation. The response is considerably more than that which can be demonstrated by the action of known irritants. The agent or combination of agents responsible is believed to be a lipid or a lipid-like compound. The protective or therapeutic response was not evident in purified preparations of cell DNA or the non-saponifiable pigment fractions (13).

RH 00064 (continued)

Recent evidence would indicate that the irradiation resistance is not due to its multicellular characteristic or to pigment as a white mutant is also resistant, neither is there any direct evidence that the DNA is markedly different from that of other bacteria. However, there is some evidence that the cells have a remarkable ability to repair damage to its DNA, a characteristic which appears to be different from the mechanism observed in resistant strains of Esherichia coli B/r (O.R.L.) (ai).

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RH 00065
RAD

"BEHAVIORAL EFFECTS OF FETAL X-IRRADIATION"

It has been known for a long time that the developing nervous system is highly sensitive to ionizing radiations. The evidence was based mainly on human clinical case reports and on anatomical studies of fetally irradiated animals. Until recently there has been relatively little quantitative information about the behavioral changes.

The present research project in which albino rats are used attempts to investigate several specific problems:

1. What kinds of behavioral changes result from irradiation at different stages of development using various dose levels? We have already reported deficits in maze learning, several types of motor activities, sexual behavior, adjustment to food and water deprivation regimens, and disturbances in general activity and "emotionality". Additional data are being collected in the area of sensory functions.

2. Are the observed changes constant throughout the animal's life span or do they become ameliorated or exacerbated as the animal ages? Should the latter occur, it would tend to support the hypothesis that radiation either mimicks or induces aging. The finding thus far indicate only partial support for the latter possibilities. in studies of motor functions, avoidance conditioning, open field activity, and cardiac reactivity there has been no evidence that the radiation effects become progressively more pronounced as aging occurs. However, in adaptation to limited food or water intake there is some indication that radiation does indeed mimic aging. The basis for these divergent findings will be investigated.

RH 00065 (continued)

Since non-irradiated animals serve as controls, we are also able to gather normative data on behavioral age changes. Several of these have been published.

3. What is the interrelationship between the various radiation-induced behavioral changes? Since there are a large number of diverse behavioral changes it seems appropriate to search for the common factors which are the basis of the observed phenomena. We are using multivariate statistical methods in the analysis of this problem. Hopefully this may be a beginning toward an embryology of behavior. It should be noted that radiation is used here primarily as a tool in the behavioral analysis.

4. Are the radiation-induced genetic changes qualitatively similar to the observed somatic effects? In the first study the offspring of male irradiated mice have been subjected to tests similar to those used with the prenatally irradiated rats. Preliminary results indicate that at least for one of the functions tested, "emotionality", the genetic changes are similar to the somatic effects. Further comparisons will be forthcoming.

5. Finally, a review of the literature on the behavioral effects of radiation covering the period 1955-1961 has been published. A review of the research for the subsequent period is being planned.

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RH 00066
RAD

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"AGING IN X-RAY IRRADIATED AND NON-IRRADIATED MONKEYS"

The similarity and differences of the effects of aging and whole-body radiation on the behavior of monkeys was examined in both longitudinal and cross sectional studies. The longitudinal studies were based on repetitions throughout a seven year span of both observational and formal laboratory procedures both of which had been used earlier to assay the effects of whole-body radiation. The cross sectional studies were based on hypotheses drawn from the clinical and experimental literature on differences in the performance of young and aged human subjects. These included studies of retroaction and transfer in concurrent discriminations, the effects of stress and threat on performance, ability to shift set (using both changes in method of problem solving and in stimulus configuration), size constancy, visual capacity, and discrimination of saturations. Additional studies were elaborated from the radiation literature or were problems that were pilot studies, unrelated to radiation or aging variables.

RH 00066 (continued)

A number of differences occurred between the performance of groups of old survivors of radiation experiments and their nonirradiated controls, and there were significant differences in the performance of the old monkeys and a control group of young animals that were the progeny of the old animals. However, there was very little evidence that the effects of radiation mimicked those of aging nor was there evidence of poorer performance of the old animals as contrasted with the young animals. In the former case the differences were consonant with other findings in the radiation literature and in the latter case the immaturity or inexperience of the young Ss.

The findings of the very extensive longitudinal studies also support this conclusion. Sorting out irradiated animals that ultimately die and reanalyzing the data of the longitudinal studies showed a strikingly selective survival of animals that do poorly on discrimination and oddity problems. Progressive chronic changes found in four tasks were: a decrement with aging in delayed response and increment in reduced cue problems in the group that had survived radiation; a decrement in performance on bent-wire detour problems by nonirradiated animals as they aged; and a complex interactive change in performance on patterned string problems. Naturalistic observations showed a sharp drop in social behavior and rise in self-care with aging. Both of the latter effects were greater in the nonirradiated controls than in the survivors of radiation.

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RH 00067
EP

"AET AND DISCRIMINATION LEARNING IN X-IRRADIATED RATS"

There is ample evidence that X-irradiation during prenatal development may result in death, morphological abnormality, and subsequent deleterious effects on learning performance. Available data suggest that some of the adverse effects of irradiation may be offset by administration of radioprotective chemicals such as mercaptoethylguanidine (MEG), when given prior to irradiation. It was the major purpose of the present series of experiments to determine if such chemoprotective substances would offer protection against the expected impairment of learning behavior in rats following prenatal X-irradiation.

The first study was designed to evaluate behavioral changes following X-irradiation on the 14th day of pregnancy, and determine if buffered 2-mercaptoethylguanidine HBr (MEG) would offer any significant protection. The second study was similar but attention was devoted to the 18th day of pregnancy. Apparatus to measure behavioral performance at 60 days of age included a Lashley III water maze, and standard Skinner boxes which employed a continuous food reinforcement schedule.

RH 00067 (continued)

In the first experiment (14th day of pregnancy) a 2 x 4 factorial design was used. The first treatment classification referred to irradiation, either control or a single dose of 150 r to pregnant female rats. The second treatment dimension was concerned with type of injection procedure 20 minutes prior to irradiation; either no injection, injection of buffering solution only, 100 mg/kg of MEG, or 150 mg/kg of MEG. Behavioral testing revealed that irradiated offspring of both sexes had a faster mean swimming time in the Lashley III maze than did nonirradiated controls, and that error commission in the maze was not related to radiation treatment. The faster swimming time of irradiated animals was taken as evidence of an increased drive state which was attributable to radiation. Irradiated rats had a significantly lower lever pressing rate in the Skinner boxes when compared to controls. The behavioral protection offered by MEG was not conclusive; while there was some indication of protection as shown by both the water maze swimming time data and Skinner box performance, the findings should be interpreted with caution.

The second experiment (18th day of pregnancy) employed a 3 x 3 factorial design, the first treatment dimension referring to radiation; either control, 150 r, or 250 r. The second classification was that of injection procedure; either no injection, injection of buffer solution only, or injection of 100 mg/kg of MEG. Other experimental procedures were identical to those used in the first study. With regard to mean swimming time in the water maze, both irradiated males and females tended to swim more slowly than controls, the effect being more marked for females; type of material injected seemed to have little effect on swimming time. For both sexes, irradiated animals made more errors than did controls, and MEG did offer some protection for both levels of radiation. Bar-pressing data from the Skinner boxes demonstrated that the irradiated rat makes fewer responses than does the nonirradiated rat. For females particularly, MEG does result in increased bar-pressing performance for both levels of radiation, although the observed magnitude of protection is probably not sufficient to be of much practical value.

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RH 00068
EP

"PHYSIOLOGICAL BASIS OF RADIATION-CONDITIONED BEHAVIOR"

Minute doses of ionizing radiation were used to produce immediate adaptive responses in rats. The results reveal that there are at least two mechanisms (in addition to the well-known phosphene effect in the visual system) by which radiation produces its effects on behavior. There is an immediate reaction to exposure which indicates that animals perceive the radiation via a sensory mechanism. Subsequent to the exposure the animals develop avoidance reactions, indicating that the radiation acts as a noxious stimulus via another mechanism characterized by a much longer latency.

A series of studies on the immediate responses to the onset of X-ray exposure demonstrated the existence of the first (perceptual) mechanism. This research showed that sleepy animals respond within seconds with behavioral arousal and also display the characteristic electroencephalographic changes which accompany activiation. Radiation (250 Kv X-ray) was also used as a warning stimulus to signal the occurence of a subsequent shock to the paws of the animal. The defensive responses to the electric shock soon became conditioned to the X-ray stimulus. In other words, the animal learned to "fear" the X-ray. This fear response was quantified by using it to interrupt an ongoing activity such as bar-pressing or drinking.

The probability of response to X-ray was found to be a function of the logarithm of the intensity (dose rate) in the threshold range (20 to 200mr/sec) and the reaction was very prompt (less than 0.1 sec). This resembles the action of peripheral sensory receptors. Studies with partial body exposure indicated that the anterior region of the head was the most radiosensitive area in this regard. Surgical experiments are now in progress to locate the receptor site more precisely.

The second (aversive) mechanism was postulated on the basis of previous studies which had demonstrated that radiation exposure acts as a noxious agent to produce avoidance reactions to stimuli associated with exposure. For example, it was shown that animals would avoid the compartment in which they were exposed. Conditioned responses have been established to saccharin-flavored water by exposing the animals

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RH 00068
EP

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The second (aversive) mechanism was postulated on the basis of previous studies which had demonstrated that radiation exposure acts as a noxious agent to produce avoidance reactions to stimuli associated with exposure. For example, it was shown that animals would avoid the compartment in which they were exposed. Conditioned responses have been established to saccharin-flavored water by exposing the animals to 10 r while they were drinking this fluid. The abdomen was found to be the most sensitive area in this regard. More recent studies under this grant reveal that the avoidance reaction is not as prompt as the perceptual response and may not be manifested until hours after exposure. In further contrast to perceptual response, the aversive response is a function of total dose and is relatively independent of the dose rate. It was demonstrated that aversions can be established by dose rates below the perceptual threshold if the exposure is prolonged so that a sufficient total dose is accumulated. This resembles the action of an internal receptor monitoring the level of a toxic product in the humoral system of the animal.

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RH 00071
RAD

"REPAIR RATE AND LIFE SPAN IN RADIATION DAMAGED MICE"

The following research, supported jointly by Research Grant RH 00071 and by contract with the U.S. Atomic Energy Commission for the period January 1, 1953 to December 31, 1963, has been completed. Two major studies utilizing 4000 mice each were carried out to determine the effect of age and previous radiation exposure on the sensitivity of populations to further radiation exposures. The following conclusions were reached: 1) Life shortening was a linear function of X-radiation dose when dose was delivered at 90 days of age. 2) A plateau in radiation resistance as estimated by the LD_{50}-30 days or survival under exposure to 100 r/day occurred which extended from young adulthood to reasonably advanced age, but the length of the plateau period was a function of genotype (strain). 3) Animals exposed to sublethal radiation doses early in life were generally more sensitive to further exposure throughout the remainder of their lives (residual injury was detectable at most time intervals). 4) A linearly increasing, permanent injury following sublethal exposure has been demonstrated by estimating percent residual injury remaining from the initial dose as a function of time (split-dose technique).

The observations of others that life shortening by radiation is less when the exposures are made at advanced ages have been confirmed.

RH 00071 (continued)

The question of whether residual injury measurable as a lowered resistance to further exposure is related to the injury leading to life shortening has been investigated. Certain similarities with respect to effects of partial shielding, age at exposure, and the administration of chemical protectants have been demonstrated.

The longevity and disease incidence of 20 inbred mouse strains has been determined to provide necessary baseline information on which to base choices of strains for aging studies.

A number of potential indices of aging which are independent of the life table have been studied. It has been concluded that the variance in a great number of physiologic measurements increases linearly with the age of the population. The ratio of wet to dry weight of the brain also provides an excellent age-dependent measurement which is not influenced by morbidity or mortality in the population. The genetics of radiation resistance has been studied in detail and a number of correlated characteristics have been identified.

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RH 00072
RAD

"LONG-TERM RADIATION EFFECTS ON SUBHUMAN PRIMATES"

The physiologic, pathologic, and behavioral effects of X-irradiation administered to rhesus monkeys in biweekly doses of 25 r, 50 r, 100 r, or 200 r was studied. The mean survival of monkeys exposed to biweekly doses of 100 r or 200 r was found to be approximately 900 r. Reduction of the biweekly exposure to 50 r, however, resulted in a bimodal distribution of survivals. Approximately 50% of the 15-animal group died prior to accumulating 1500 r, while the remaining animals survived a cumulative dosage of 3000 r. Animals in the latter group survived for periods of 11 to 26 months following the last irradiation exposure. The results of these biological studies have been analyzed and are presently being prepared for publication.

Adrenocortical function was investigated in selected animals from the 100 r and 200 r groups. Significant elevations in plasma concentrations of 17-hydroxycorticosteroids were observed four hours following an irradiation exposure and generally again just prior to death. The increased steroid levels could not be attributed to a decrease in cortisol metabolism since no significant difference in cortisol half-life was observed between irradiated and sham-irradiated monkeys. Of particular interest was the observation that adrenocortical capacity, as measured by the increase in 17-hydroxycorticosteroids following exogenous ACTH was also elevated in the irradiated animals. (This data is now in press in Radiation Research.)

The protective effects of aminoethylisothiouronium bromide (AET) and cysteine in rhesus monkeys receiving a single lethal total body exposure to X-irradiation was also investigated. The results of this study demonstrated that 11 of 14 animals exposed to a single dosage of 800 r died within 30 days following irradiation. If, however, AET and cysteine, together with epinephrine were administered immediately prior to irradiation, 35% of the irradiated animals would survive for at least 30 days. Moreover, these studies indicated that in protected monkeys a marked cellular regeneration of both spleen and bone marrow were clearly evidenced within the 30-day period following irradiation. In addition, one year following irradiation a surviving female became pregnant. In this animal, however, parturition was delayed and a nonviable fetus was removed at Cesarean section.

Further studies utilizing radioprotective agents are continuing. The specific areas being investigated include: a) the effects of radioprotective agents on the regenerative and reproductive capacity of irradiated monkeys, b) the efficacy of these agents in protecting the early embryonic stages of development in lethally irradiated rats and monkeys, and c) the efficacy of homologous and autologous bone marrow transplants in irradiated monkeys.

Behavioral effects of 50 r , 100 r, and 200 r biweekly were assessed using an extensive battery of tests. Measures were taken of visual exploration, food motivation, discrimination and oddity problem solving ability, delayed response, and avoidance behavior using cold water as the aversive stimulus. In general, no behavioral deficits were noted except in the terminal few days of life when the monkeys were physically debilitated. Exceptions to this included measurements of food motivation and the ability of female monkeys of the 50 r group to solve oddity learning set better than the males. This sex effect is similar to that reported by McDowell, Brown and colleagues. It is of further interest in the present case since it might be related to the fact that of the six 50 r monkeys surviving to 3000 r, five were males.

In addition to the above, studies were also done on rats and monkeys confirming the Kimmeldorf-Garcia finding that radiation can serve as an aversive stimulus in reversing preferences for fluids drunk while receiving low doses of X-irradiation.

Since most results were negative, it is planned to collect all behavioral studies together into a single summary publication.

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RH 00075
RAD

"A COHORT STUDY ON SURVIVORSHIP AND MORTALITY OF RADIOLOGISTS"

This study was designed to test the hypothesis that the type of occupational exposure to ionizing radiation sustained by radiologists has an unfavorable effect on survivorship. It is an attempt to come to grips in a human population with one of the most intriquing biological effects of ionizing radiation which has been observed consistently in studies with experimental animals and has been described variously as "nonspecific life shortening", "premature aging" or "accelerated aging". Various groups of physician specialists have been classified according to their presumed degree of occupational exposure to ionizing radiation; the membership rosters of physician specialty societies have been reconstructed from a given point in time; the current survivorship status of all physicians who ever entered these societies has been determined; and causes of death obtained for the deceased members. The purpose has been to obtain age-specific, cause-specific and calendar-time specific death rates for these various groups, in order to demonstrate, if present, gradients of mortality between these specialties which would be consistent with the postulated gradients in occupational risk of exposure to ionizing radiation. The specialty groups studied included the "high-risk" radiologists; "low-risk" opthalmologists and otolaryngologists; and" intermediate-risk" orthopedic surgeons, internists, and pathologists. Data has been successfully collected on over 19,000 specialist physicians, and complete survivorship information is available on over 99.5% of these. A total of 5200 deaths have occurred among these specialists since 1915, 1265 of them among the radiologists.

Analyses completed to date have revealed that there is, in fact, a demonstrable gradient of mortality progressing from highest mortality rates in the radiologists down to lowest rates in the ophthalmologist-otolaryngologist groups; that this gradient is most marked in the older age groups and is present in all of the calendar-time periods studied. The mortality gradient is present not only for all causes of death combined, but is also seen for cardiovascular-renal diseases, cancer and most other causes. There is strong suggestion that changes in radiological practice since the 1930's have brought about a decrease

RH 00075 (continued)

in the occupational hazards to which radiologists have been subjected, and there is no evidence of increased mortality in the age groups 35-49 for any of the calendar periods since 1945. The findings do, however, warrant the inference that the type of occupational exposure to ionizing radiation sustained by radiologists in the past have produced effects on survivorship which may be similar to the "nonspecific aging" effect which has been described in populations of radiation-exposed experimental animals.

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RH 00078
RAD

"EFFECTS OF IRRADIATION ON AGING OF SMALL ANIMALS"

Experiments were designed to test (1) the relative effectiveness of moderate hypothermia in protecting young and adult rats from the effects of an LD 70/30 of X-rays, and (2) to seek information on the effect of radiation on enzymes of the rat brain.

Moderate hypothermia (22 degrees to 25 degrees C.) was induced in rats by keeping them in iced Mason jars in a room cooled to 0 degrees C., and transporting them to the radiation facility in an ice-cooled chest. Rectal temperatures were measured just before irradiation. The rats were then exposed to whole-body irradiation by X-rays (250KV, HVL 0.88 Cu), and subsequently allowed to return to normal temperatures. To facilitate cooling of the rats, and to decrease spontaneous motor activity, medication with chloropromazine, 10mg/kg., I-P, or with pentobarbital, 35mg/kg., I-P, was given three hours before irradiation. Control groups were used for each experiment. Comparisons of survival rates between rats cooled physically and those cooled with the addition of each of the chemical agents have been made for young rats. Physically-induced hypothermia was significantly more effective than that induced pharmacologically in improving 30-day survival rates following irradiation, and simultaneous use of physical cold and a chemical agent was additive in effect with chlorpromazine but not with pentobarbital. The latter was not effective alone, either, as a pre-irradiation protective agent. These experiments are being duplicated with older rats.

The effects of 1000r of total-body x-irradiation on enzymes in the rat brain were studied. Glutathione reductase, the enzymes in the glycolytic and hexosemonophosphate pathways were not affected even in prolonged postirradiation intervals of ten days. Examination of the activities of nucleoside phosphorylase, and nucleotidases (both DNA-ase and RNA-ase) also showed no postirradiation effects. It was concluded that X-ray doses up to 1000r do not influence brain enzymes in contrast to the effect of such exposures on rat marrow or spleen.

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RH 00080
HED

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"PROTECTION AGAINST PRENATAL X-IRRADIATION"

The radioprotective agents AET, cysteamine and MEG largely prevented the occurrence of foot deformities and a defect in gait (which was unrelated to the foot deformities) in the young of rats exposed to a single dose of 150r total body x -irradiation on the 14th day of pregnancy. These substances also prevented in part the occurrence of an abnormality in the development of the cerebral hemispheres of such young but were without significant effect in altering an attendant reduction in the ratio of brain to body weight. MEG and cysteamine also largely counteracted the occurrence of aspermatogenesis, degenerative changes in the germinal epithelium, and reduction in testes weight in the offspring of rats exposed to a single dose of 150 r total body x-irradiation on the 18th day of pregnancy. MEG, however, did not reduce the high incidence of anophthalmia and microphthalmia in the young of rats exposed to a single dose of 150 r total body x-irradiation on the 18th day of pregnancy. MEG , however, did not reduce the high incidence of anophthalmia and microphthalmia in the young of rats exposed to a single dose of 150 r total body x-irradiation on the 10th day of pregnancy or the increased caries susceptibility of such young. It would appear that radioprotective agents differ in their capacity to protect against various manifestations of radiation injury in the prenatally x-irradiated rat, although the possibility that the above findings may reflect differences in the dose of radioprotective agent required by different organ systems has not been excluded.

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RH 00081
RAD

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"AGING AND OTHER SEQUELAE OF FETAL X-IRRADIATION"

CF1 mice have been time-mated within 2 hours and the embryos and fetuses x-irradiated to 1 r, 10 r, and 100 r at each of the various gestation ages from fertilization through day 18. The offspring have been studied for radiation sequelae during their life span of 3.5 years, and the results of irradiation on the skeleton and cataractogenesis have been completed and are in press.

The skeletal study was made when the mice had reached 4 months of age, and consisted of 1,005 radiograms from which exact measurements were taken of the skull (AP and LAT), spine, humerus, ulna, femur, and tibia. There were approximately 25 mice of each sex for each gestation age, exposed in utero to 100 r X-rays. The data are presented in tabular form, and are statistically analyzed. There are sex differences in skeletal growth, with the maximum reaction when the mice were 12 days of gestational age. Stunting was found thoughout development, following irradiation. (Am. Jour. Anat. in press).

Mice exposed to 100 r X-rays in utero and examined at 3, 6, 9, and 12 months of age, and again at 18 months, showed statistically significant increase in the incidence of cataracts. These appeared earlier and in greater frequency among the irradiated than among the control mice. The study involved 14,656 slit lamp examinations of mouse eyes, and another 2,000 at 18 months. The data are presented in graphic form, and show that the gestational age when x-irradiation causes the greatest increase in cataracts is immediately after fertilization. At 12 months of age the males and females showed about 70% incidence of cataracts while the controls showed less than 10%. At 18 months both the males and females irradiated at fertilization showed at least 97% cataracts, while the control females showed 17% and the control males 13%. Thus, x-irradiation prior to cleavage, prior to implantation, prior to any suggestion of organogenesis caused a tremendous increase in the incidence of cataracts. There were other gestation ages which gave a significant increase in cataracts, namely days 2,4,9,15, and 17. It is suggested that the damage at fertilization may be to the chromosomes, and at post-organogenesis stages may be to the developing lens.

Out of the embyonic and fetal studies has come a finding of some significance, namely that whole body irradiation causes the appearance in the peripheral blood of anomalous lymphocytes, cells with cytoplasmic inclusions. This too was a finding out of work supported by RH 00081, and was so reported in the Am. Jour. Roent. Rad. Ther. & Nucl. Med. 91:192-201, 1964.

This is a partial report of work accomplished under PHS Grant RH 00081.

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RH 00086
RAD

"STUDIES ON THE POSTNATALLY DEMONSTRABLE EFFECTS OF IN UTERO IRRADIATION OF THE RAT"

Pregnant female rats were irradiated with 20 or 100 r of X-ray after 10 days of gestation or with 50 or 185 r after 15 days of gestation. At the time of birth, two males and two females randonly selected from each sex within each experimental and control group were used, as of the time of weaning. These rats were weighed and examined at birth and at frequent intervals thereafter. Blood counts and urinalyses were performed and complete autopsies obtained at the time of death. A second colony of similarly treated animals was used for studies in which sacrifice of the animal was required.

Radiation with 185 r after 15 days of gestation increased the incidence of stillbirth and of neonatal mortality. They continued to show extensive mortality for a large portion of their life span although the other groups displayed mortality curves quite similar to those of the control. The animals of this group were smaller than the controls at the time of birth and grew at a lower rate throughout life. Organ weight, expressed as percent of body weight, was also determined throughout life. The relative weight of the brain was substantially reduced at the time of birth although it ultimately attained the same relative size as the controls. There was also a decrease in the relative weight of the gonads, which remained small throughout life. The animals treated with 50 r at this time or with 100 r at 10 days of gestation showed a similar although much less pronounced reduction in relative organs. Crude assays indicated that there was a greatly reduced production of ovarian hormone in the 15 day - 185 r females.

The malformations observed in these animals were largely those which were expected on the basis of the literature. However, a number of the experimental animals were noted to have a variety of neurological deficits, which were studied in detail. The incidence and severity of these deficits was greatest in the rats treated with 185 r after 15 days of gestation and lower but still appreciable in the remaining groups.

There was evidence of hemoconcentration at birth in both of the groups exposed after 15 days of gestation. At the higher dose, this was accompanied by a pronounced leukopenia at birth, from which recovery had been obtained by one week of age. These animals displayed a relative leucocytosis at 18 months of age which continued. Many females of this group developed a persistent albuminuria at about the same age, which was the only evidence of renal malfunction.

There was a substantial increase in the average number of mammary tumors per female rat in three of the four experimental groups. This was statistically significant only in those treated with 100 r after 10 days of gestation although nearly as high an incidence was seen in the other two groups. The exception was in those animals treated with 185 r after 15 days of gestation, in which a substantially decreased number of mammary tumors appeared.

In corollary studies it was found that there was a tendency toward a depression of the radioiodine-incorporating ability of the thyroid glands in the experimental animals which was most pronounced after irradiation at 15 days of gestation. The LD-50, measured at 90 days of age, was significantly reduced in the animals treated with 185 r at 15 days of gestation. A lesser and not significant decrease in the LD-50 was seen after radiation with 100 r after 10 days of gestation.

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RH 00089
RAD

"X-RADIATION PROTECTION BY CHEMICAL AGENTS IN GUINEA PIGS"

In previous studies we have demonstrated the protective effect of the sodium salt of ribonucleic acid against a lethal X-ray dose in the guinea pig. In the current experiments x-radiation protection with the disodium salt of **adenosine 5'-triphosphate (ATP) has been** studied. Female guinea pigs of 300 to 400 gms. body weight were used in the experiments. In following up the animals the criteria for protection were the survival rate of the protected animals beyond the mean survival time of the nonprotected controls; the trend of the weight curves; hematogological patterns; and reproductive capability. The X-ray dose was 295 r.*) (total body irradiation; factors: 260 KV, 15 MA, 1 mm. al 0.5 mm. copper, 50 cm. distance, MVL 1.2 mm. copper). Forty two animals were injected subcutaneously with 1 ml. of a 10% solution of ATP**) in physiological saline before and after irradiation, and 39 animals served as controls. ATP has occasionally an immediate toxic effect characterized by weakness, polypnea and paralysis of the hind legs. Approximately 6% of the animals succumbed to the injection per se, but the majority either did not show any ill effect at all or recovered from the initial shock within a few hours.

Only nine animals of the 39 controls survived (23%). The mean survival time of the fatal cases was 12.5 + 1.7 days. On the other hand, 34 of the 42 injected animals survived (81%). After five to six weeks following irradiation the experiments were terminated. When 60 mg. were injected before and after irradiation instead of 2 x 100, protection could not be achieved. Seven out nine animals succumbed. With only 1 x 100 mg. before and no reinjection following irradiation the protection is much less effective; only six out of 15 animals survived (40%) , but some of the animals that finally died lived up to three to four weeks, much longer than the unprotected controls. When the injections were not given simultaneously with irradiation, but on the following and the next following day, no protection could be achieved. The death rate was the same as that of the nonprotected controls. The bone marrow damage inflicted by irradiation is obviously irreversible and the drop in the leukocyte count was just as abrupt as in unprotected animals.

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* The LD_{50} for the guinea pig is 200 r.

** Adjusted with sodium hydroxide to a pH of 7.0

The weights of the animals were recorded daily. In general the survivors show a steady gain in weight and only insignificant flucuations of the weight curve. In the fatal cases, on the other hand, the weight curve is less steady; a sudden drop in weight of 50 gms. or more is usually followed by death within a day or two. However, this does not hold for all animals. Occasionally an animal may succumb from one day to the next without any warning. In the more protracted cases enophthalmus and conjunctival secretion can be noted.

Leukocyte counts and hematocrits were recorded every other day. Following the initial drop of the leukocytes to rather low values the counts increase after approximately three weeks and reach normal levels after four weeks. In the unprotected animals the drop to extremely low values the counts increase after approximately three weeks and reach normal levels after four weeks. In the unprotected animals the leukocytes drop to extremely low values, such as 600 to 800 per mm^3. Recovery is no longer possible. The hematocrits may likewise drop to markedly reduced levels in the protected animals and return to normal values along with the leukocytes. However, the trend of the leukocyte and erythrocyte response to irradiation is not in all instances the same. The leukopoietic system of the bone marrow seems to be more sensitive to the damaging effect of irradiation than the erythropoietic. In several controls the hematocrit was still within normal limits, while the leukocytes were reduced to a few hundred cells per mm^3 and the animal succumbed. In general a drop of the leukocyte count below 1000 per mm^3 indicates that the animal is lost, while a normal hematocrit does not necessarily mean that the animal is protected.

Other studies are concerned with the problem of whether or not ATP administered early in pregnancy is able to protect an irradiated animal through the gestation period and to guarantee the delivery of a normal litter. So far our experience is limited to one observation. In a series of ten animals one of them happened to be in an early stage of pregnancy. It was irradiated with 295 r and injected with 100 mg.

RH 00089 (continued)

ATP before and after irradiation. After 52 days the animal gave birth to three normal male animals. They did not show any congenital anomalies and developed normally. Further studies on ATP protection of pregnant guinea pigs are in progress.

The protective effect of ATP is almost the same as that of sodium ribonucleate (81% versus 78% protection). It should be emphasized that ATP is essential in the synthesis of ribonucleic acid.

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RH 00092
RAD

"EPIDEMIOLOGICAL APPLICATION OF X-RAY DOSIMETRIC DATA"

This project is an exhaustive study of the radiant energy delivered to forty thousand patients given diagnostic examinations at The Johns Hopkins Hospital. Measurements are being made during radiographic and fluoroscopic studies. The data are being collected with an integrating ionization device designed to measure directly in units of radiant energy. The device is placed beyond the cone or shutters associated with the X-ray tube and is of such size that all of the radiant energy projected toward the patient is measured.

The measurement of the radiant energy delivered to patients in diagnostic radiology may be expected to have two principal values: 1) resultant data may be useful in epidemiological studies of the quantitative relationships existing between radiation dose and biological effect and 2) the data may be of value in the assessment of the operating practices of a physician or technician in the use of his or her equipment.

The determination of the dose-effect relationship for any critical tissue requires that specific information be available concerning the dosages received by the tissue in question. Hence, the epidemiologist in studying radiation-related disease in populations on which diagnostic X-ray examinations have been performed, must have at his disposal reliable quantitative data on the radiation dose delivered to each appropriate critical tissue during these examinations. For highly localized tissues such as the reproductive organs and the thyroid gland, such data are theoretically not difficult to obtain. Dosimetric instrumentation is available with which direct measurements of dose may be made at or near most of the tissues of interest.

RH 00092 (continued)

The dosimetric problem for the epidemiologist becomes more complex when the critical tissue is not localized, as in the case of the hematopoietic system. Under these circumstances, direct measurements of dose require the use of recording devices located at a large number of positions over the body to obtain the needed data. Another approach to this problem is the measurement of the radiant energy delivered to the patient at each examination together with a careful recording of the body location to which the radiation is delivered. In this project the latter course is being followed.

Since ionizing radiation may produce undesirable biological change, the physician must avoid all unnecessary radiation in his medical practice. Unnecessary exposure may result from three main causes: 1) the use excessively large fields of irradiation; 2) the use of unnecessarily high radiation intensities and 3) the use of unusually long exposure times. Excessive fields of irradiation constitute the principle problem in radiography. Because abnormal intensity levels and/or exposure times result in diagnostically poor films, the physician and technician are usually restrained from excesses in these directions. In fluoroscopy, however, all three factors may contribute to unnecessary exposure.

Conventional dosimetric apparatus which measures dose rate may be used to indicate radiation intensity. Instruments which measure dose may also be employed as indicators of the product of radiation intensity and exposure time. Neither type of instrument, however, indicates excessive field sizes. By the use of the instrumentation employed in this project, where total radiant energy is measured, a direct correlation may be obtained between the extent of undesirable technical practices and the individuals responsible for these practices. This project therefore is secondarily designed to evaluate the extent to which unnecessary radiation is employed in routine diagnostic X-ray practice.

The final phases of data collection are now in progress and data analysis should be complete with subsequent reporting later this year.

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RH 00095
RAD

"MECHANISMS OF RADIATION EFFECTS - INACTIVATION OF ENZYMES BY IONIZING RADIATION"

The present investigation is a study of the effects of gamma irradiation on aqueous solutions of the enzyme ribonuclease A. The work is part of a general approach to a better understanding of radiation effects through studies of isolated biochemical systems. There is particular interest in such key constituents of the cell as enzymes and nucleic acids. Ribonuclease is a choice model for study, since its structure is known, and since it is now possible, because of numerous investigations into modifications of the enzyme's structure, to define several requirements for its activity.

In addition, a basic problem in radiation chemistry is the evaluation of the role of free radicals from water when irradiations are carried out in aqueous medium. Increasing evidence points to the importance of this "indirect effect" and to the need for definition of the chemical changes mediated by free radicals.

The present study is proceeding along several lines of interest.

In earlier work, it was noted that chromatographic patterns of irradiated RNase A were very similar to those of RNase A treated with chemically generated OH radicals. Both types of inactivated samples showed new enzymically active components. These observations led to the conclusion that OH radicals are important intermediates in the radiation effect.

Current studies are attempting to define the structural characteristics of irradiated RNase A: analyses are in progress to evaluate covalent alterations in structure (e.g., oxidative, reductive, peptide bond cleavage, amino acid destruction, cleavage of S-S bridges), as well as alterations in molecular configuration. Thus, studies are made of amino acid composition, free C = O groups, free SH groups tyrosine hydrogen bonding, digestibility by trypsin, ultraviolet absorption spectrum, and the possibility of disulfide interchange.

RH 00095 (continued)

Several observations suggest that irradiated enzyme has a "loosened" molecular configuration; it is digestible by trypsin (in contrast to native RNase A), shows evidence of a broken disulfide bridge, and lacks the 3 tyrosine phenolic hydrogen bonds of native RNase A. Evidence of the reductive cleavage of an S-S bridge is being sought through direct titration of SH groups and through conversion of SH groups to a known radioactive derivative. The problem of reductive cleavage of S-S bridges is very relevant, both in terms of evaluating the importance of reducing radicals (i.e., H. or $e^{-}aq$.) in aqueous irradiations, and in terms of defining specific inactivating alterations in enzyme structure.

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RH 00097
RAD

"FETAL X-IRRADIATION, DIFFERENTIATION, AND FERTILITY"

Pregnant CFL mice were x-irradiated to 25 r and to 100 r at each of the gestation ages from fertilization through day 18, the offspring were separated as to sex at weaning, and were tested for fertility beginning at 2 months of age throughout their life span. The initial study on the males has been reported (Atompraxis 10:33-41, 1964).

For the males it was found that 100 r exposure on days 10.5 through 12.5 showed a slight but statistically significant reduction in fertility, in terms of litter numbers rather than litter sizes. It was suggested that this partial sterility might be a reflection of general debility.

Neonatal males (birth to 2 months) showed no effect of 100 r exposure on subsequent fertility, but exposures of 400 r did affect fertility, especially among those exposed at 1 and 2 months of age. Examination of the testes of mice at the termination of the experiment showed that in some cases most of the testis had been damaged by irradiation, but that from a portion of a testis, undamaged by X-rays, there could regenerate almost an entirely normal and functional gonad. It was concluded that the unformed, undifferentiated testis, and the actively maturing testis, are both sufficiently radioresistant to make full recovery if a few spermatogonia escape irradiation death.

RH 00097 (continued)

A similar study was made of embryonic and fetal females, exposed to 30 r and 100 r, and also to neonatal females from birth through 2 months of age. In contrast with the male, it was found that the female was the more radiosensitive, that the most sensitive period was not prenatally but during the second and third postnatal weeks. During this period it was shown that there are abundant oogonia undergoing their first maturation changes and hence are particularly radiosensitive, It was found that in a few cases there seemed to be temporary sterility of a particular female, which later resumed fertility. This paper has been sent to press (Atompraxis) and should appear within the next few months.

The study has pointed up several important new considerations. First, it has developed that sterility as measured by litter production and size, over an extended period, is not a measure of ovarian sterility but rather of overall female fertility. That is, an ovary might still produce ova, the female might allow mating and have copulation plugs, but still be unable to produce fetuses. Further, there has developed a condition of abortion, persistent amnions, giant and undeliverable fetuses, all of which affect the production rate and hence confuse the data on sterility. Thus, the current study is an attempt to differentiate between ovarian sterility and physiological sterility of the female. This requires individual attention to each mouse, among several thousand that now comprise the fertility-sterility study.

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RH 00098
RAD

"ENZYMATIC AND ESR STUDIES OF RADIATION DAMAGE"

The appearance and migration of unpaired spins in irradiated molecules of biological interest are being studied by qualitative and quantitative ESR spectroscopy, methods permitting observations to be made with minimal interference with the system under study. Since the secondary processes in irradiated substances frequently occur too rapidly to permit experimental observations the studies are to a large extent carried out at very low temperatures.

Dry proteins, amino acids and various sulphur-containing cysteamine derivatives have been studied, singly and in mixtures. The substances are irradiated at liquid nitrogen temperature (77°K) and the ESR spectra are recorded. Subsequently the samples are exposed to controlled heat treatments at different temperatures and for different lengths of time and the spectra are again recorded after cooling to 77°K. The studies throw light on the factors influencing the rate of migration of unpaired spins to sulphur atoms and on the nature of the transfer of spins in dry molecular mixtures.

The events in irradiated ice and in frozen solutions of proteins and amino acids are studied with a similar technique. By ESR spectroscopy at low temperatures the nature, yield, and stability of the water radicals are investigated as a function of the pH and the crystallinity. The experiments on the solutions are designed to give information on the nature and extent of the indirect action in frozen aqueous systems. The number of solute radicals is studied as a function of the concentration of the solutes and of the irradiation temperatures. The results indicate that there is an appreciable indirect effect even at the temperature of liquid nitrogen.

ESR studies of DNA and of its constituents are under way. Quantitative ESR measurements are carried out on the individual nitrogenous bases as well as on the necleosides, nucleotides and the corresponding di-, and triphosphates. The results are compared with those obtained on DNA samples having different base compositions and with the results obtained in mixtures of nucleotides, mirroring the base composition of the DNA samples. The results on the isolated DNA's will be correlated with the biological radiation effects on the bacteria from which the DNA samples are isolated. It is hoped that the results will contribute to the understanding of the role of the DNA in radiation damage.

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RH 00099
RAD

"RBE OF MONOENERGETIC NEUTRONS"

The mean linear energy transfer of the charged particles set in motion by neutrons is a function of neutron energy. It can be shown that the curve relating mean LET (Dose average) to neutron energy rises from comparatively low values to a maximum mean LET of about 70 kev/u for a neutron energy of about 275 kev and then decreases steadily as the neutron energy increases further. This suggests that the RBE of fast neutrons may be a similar function of neutron energy. Consequently a series of experiments has been initiated in which RBE is studied as a function of neutron energy. Monoenergetic neutrons are produced by interactions of various hydrogen isotopes. Usually several energies are utilized simultaneously by placing biological materials at various angles to the bombarding beam and at such distances that the dose rate is essentially the same. The irradiation facility, dosimetry and some biological results have been described in a number of publications: H.H. Rossi, J.L. Bateman, V.P. Bond, L.J. Goodman, and E.E. Stickley, The Dependence of RBE on the Energy of Fast Neutrons 1. Physical Design and Measurement of Absorbed Dose. Radiation Research 13, 503-520 (1960)

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J. L. Bateman, V. P. ond, H. H. Rossi, Early and late effects of "monoenergetic" fast neutrons in mice. IAEA Symposium, Brookhaven National Laboratory, October 1963. (In press)

H. H. Smith, J. L. Bateman, H. Quastler, and H. H. Rossi, RBE of "monoenergetic" fast neutrons: cytogenetic effects in maize. IAEA Symposium Brookhaven National Laboratory, October 1963. (In press)

RH 00099 (continued)

Briefly it was found that RBE is substantially proportional to the dose average LET in the range from about 200 kev to 1.8 Mev for all biological effects and energies investigated thus far. However, the proportionality factor is variable. The effects investigated include loss of spleen weight, loss of thymus weight, uptake of I-131-labelled iododioxyurine, killing of spermatogonia and cataract induction. All of these were investigated in the mouse. In addition a particular type of somatic mutation (yg2) in maize was also studied. In this instance RBE values up to 100 were found relative to X-rays.

In future experiments the range of neutron energies is to be extended to 14 Mev and additional effects may be studied also.

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RH 00114
MET

"THE EFFECT OF FLUORIDE ON SKELETAL RETENTION OF Sr^{90}"

Increasing numbers of communities using fluoridated drinking water along with the increasing amount of radioactive strontium in the atmosphere have caused considerable speculation whether the mutual presence of fluoride and strontium increases the retention of each of these elements within the body. A series of studies were therefore conducted to investigate the relationship existing in the metabolism of these elements.

One study designed primarily to investigate the effect of $strontium^{89}$ upon fluoride metabolism in the rat was conducted and has been reported in detail. This study involved three different series of animals with each series differing in the level of $strontium^{89}$ and fluoride administered and the duration of the experimental period. The supplemental fluoride levels ranged from 0.15 mg to 1.00 mg per day and the experimental periods ranged from 10 to 100 days. The effects upon fluoride and $strontium^{89}$ metabolism were determined by analysis of the urine, feces, femur, and remaining carcass of each animal for both elements.

The data obtained in this study indicated that the administration of strontium^{89} and fluoride together did not increase the retention of either strontium^{89} or fluoride in the whole carcass or femur of the rat. In fact, the data suggested that the presence of fluoride may be associated with a decrease in the amount of strontium^{89} retained by the rat. Excretion data tended to support this latter tendency with the presence of fluoride being associated with significantly more strontium^{89} being excreted in the feces and significantly less strontium^{89} appearing in the urine.

A second experiment was performed which was again designed to appraise the potential benefits or hazards that may exist in the consumption of fluoride in an environment contaminated with bone-seeking strontium-90. However, this study differed from the previous investigation in that it was designed to provide data both on the uptake and retention of calcium (as Ca^{45}) and strontium (as Sr^{89}) in rats receiving different levels of fluoride (as sodium fluoride) under conditions which avoided the possibility of an interaction of the experimental ions with fluoride in the gastrointestinal tract.

A total of ninety-six male weanling rats were divided into six equal groups according to body weight and were maintained in metabolism cages for a thirty-day experimental period. In order to insure that no difference in the metabolism of the experimental elements might be due to variations in food consumption all animals were force-fed a specially prepared diet throughout the experimental period. The radiostrontium and calcium were administered daily by intraperitoneal injection while the fluoride was provided daily by stomach tube thereby eliminating any possible interaction within the gastrointestinal tract. During the entire period the diet and fluoride was supplied separately by stomach tube. One-half of the animals in each group were sacrificed after the thirty-day exposure period and the remainder were maintained for an additional thirty days without additional fluoride, Ca^{45} or Sr^{89} administration.

At both sacrifice periods, representative bones were removed from each rat and were ashed and analyzed for fluoride, calcium, phosphate, strontium^{89} and calcium^{45}. Fecal and urinary metabolism samples were treated similarly. The results obtained from these analyses indicated that fluoride does not have a significant effect on the metabolism of strontium (as Sr^{89}) under the conditions employed in this study. These data, when considered in light of the previous work suggest that any alteration in strontium metabolism due to the presence of fluoride may be partially explained by an interaction of these elements within the gastrointestinal tract resulting in a decreased absorption of radiostrontium from the gastrointestinal tract.

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RH 00116
RAD

"ALTERATION OF GENETIC REPLICATION"

Previous work has demonstrated that the incidence of lethal mutations in Drosophila is reduced if irradiated males are cultured on media containing penicillin or actinomycin D (1,2). These observations are now being extended to experiments on mice in order to determine whether a similar reduction in lethal mutations induced by irradiation can be obtained in mammals by treatment with antibiotics. The initial exploration is being conducted by determining the incidence of dominant lethal mutations in A-strain mice treated with penicillin by the method described by Bateman (3). Additional groups include irradiated mice, mice injected with the diluent, nonirradiated mice treated with penicillin, and mice without treatment. Twelve days after mating the number of implantations (Imp.), preimplantation embryonic deaths (Pre), early deaths of embryos (ED), and late deaths of embryos (LD) are tabulated. The incidence of dominant lethals is then calculated as $\frac{\text{ED}}{(\text{Imp} - \text{ED})}$. At this time our data indicate that when mating occurs four to seven days after irradiation, there are significantly fewer dominant lethal mutations in male mice treated with penicillin prior to irradiation than in those that did not receive the antibiotic. For matings that take place during the second and third week after irradiation, a similar reduction in the incidence of dominant lethals was found, but the numbers of matings were too small for these data to be conclusive. Experiments with larger numbers of mice are in progress to determine the effect of antibiotics during this period. Penicillin does not appear to affect the incidence of dominant lethals in mice that are not irradiated. Cytologic techniques will also be employed to determine the effect of antibiotics on chromosomal aberrations produced by irradiation both in germinal and somatic cells.

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RH 00139
PTHB

"EFFECTS OF ZIRCONIUM CITRATE ON STRONTIUM-90 BONE CANCER."

Young virgin female mice of the CF_1 strain were given Sr^{90} intraperitoneally (i.p.). Three cancerogenic doses were used: "high" dose, 0.44 uc/gm.; "intermediate" dose, 0.34 uc/gm.; and "low" dose, 0.20 uc/gm. Each of these three dose levels was further divided into "a", Sr^{90} alone; "b", Sr^{90} plus zirconium citrate; and "c" (in the high dose level only) Sr^{90} plus zirconium citrate and sodium acetazolamide, a diuretic called "Diamox". There were seven experimental groups of 500 mice each.

In the "b" groups, the initial i.p. injection of zirconium citrate was given exactly 15 minutes after Sr^{90} , followed by three more injections of ziroconium citrate at succeeding hourly intervals. The first i.p. injection of Diamox was given one hour before Sr^{90}, and the second injection simultaneously with the last dose of zirconium citrate.

Periodic sacrifices were carried out at 6,8,10,12, and 16 months after Sr^{90} injection in order to obtain representative samples for study of radiation injury and early tumor changes. Detection of bone tumors was based on daily inspection, bi-weekly physical examination, terminal roentgenogram, and autopsy. For the sake of uniformity, bone tumors detected by microscopy only were not included in the present data. Only animals which had gross or radiographic evidence of bone tumor were considered. Histologic confirmation of bone malignancy was made for these animals. The time elapsing between Sr^{90} injection and the first evidence of tumor was noted for each animal, and the number of tumors in each animal.

The tumor-bearing mouse was taken as the statistical unit in this experiment. Frequency of tumor animals in each group was calculated by dividing the number of animals with tumor by the number which survived beyond the minimum time to tumor appearance (147 days).

The "a" groups served as controls to establish the "normal" frequency of tumor animals for each dose level of Sr^{90}. Frequency of tumor animals in zirconium citrate groups ("b" groups) was approximately one-third to one-half the frequency in the corresponding "a" group at all Sr^{90} dose levels studied. This was attributed to increased excretion and lowered retention of Sr^{90} effected by ziroconium citrate.

RH 00139 (continued)

External body measurements of radiation made from intact animals at 10 and 12 months after Sr^{90} injection substantiated that the "body burden" of Sr^{90} was indeed significantly reduced in all ziroconium citrate groups. Body burden was reduced by approximately one third in zirconium citrate-treated groups.

Application of appropriate statistical formulae to the data on body measurements and the data on frequency of tumor animals showed that the differences between zirconium citrate groups and respective untreated groups were highly significant. No additional beneficial effect on body burden or tumor frequency was demonstrated with Diamox.

The mean time to tumor appearance was the same in treated and untreated mice injected with the high dose of Sr^{90}, whereas the mean time in zirconium citrate mice injected with the intermedicate and low doses of Sr^{90} was 51 days and 34 days longer, respectively, than the corresponding untreated groups.

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RH 00140
RAD

"ANTIMITOTIC CHEMICALS AS PROTECTION AGAINST RADIATION"

Antimitotic compounds are under investigation as to possible protection against radiation-induced genetic effects. The metaphase inhibitor colchicine and general mitotic inhibitor urethane, the antimetabolites, 8-azaguanine and 6-purinethiol are tested in *Drosophila melanogaster*. These compounds are either fed to the larvae or injected into 4 to 16 hour old males which are then irradiated by 100Kv X-rays and mated at a ratio of 1 male to 3 females. The offspring are examined for induced recessive sex linked lethals and translocations between II and III chromosomes by means of $\underline{yB}/\underline{sc}^{8}y^{+}$, $\underline{y}$ $\underline{sc}^{SI}\underline{In}$ $\underline{49}$ $\underline{sc}^{8}$; $\underline{bw}$; $\underline{st}$ $\underline{p}^{P}$ stocks after the method of Oster. Information as to whether the change in radiosensitivity, if any, for mature spermatozoa, spermatids, spermatocytes and spermatogonia are determined by means of the successive brood technique. Data is also obtained on whether these drugs afford protection against radiation-induced loss of an X chromosome or Y chromosome containing y^{+} by the XO method in which treated $\underline{X}^{c}\underline{yB}/\underline{sc}^{8}\underline{y}^{+}$ males with a ring or closed X chromosome are mated to $\underline{ywf}$.

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RH 00186
RAD

"RADIOSENSITIVITY OF EXTRAMEDULLAR ERYTHROPOIESIS"

A very great number of investigations were carried out on the radiosensitivity of medullar hemopoiesis. In fully grown mamalia extramedullar hemopoiesis is not often met. Irradiation of mice which depresses erythrocyte formation in the bone marrow of the mouse was found to increase the rate of splenic hemopoiesis suggesting the greater radioresistance of the last-mentioned organ. Furthermore erythropoiesis in the liver of the mouse foetus was found to be less radiosensitive than that taking place in the blood forming organs of the adult animal. We meet extramedullar hemopoiesis very often in other animals than mamalia. In most fish the erythropoietic organ is the spleen or the kidney. We investigated the radiosensitivity of the erythrocyte formation in the tench in which the kidney is the hemopoietic organ. For Fe^{59} incorporation into the erythrocytes we need 750 rad Co^{60} radiation, while in the mouse 20 rad suffice to obtain a similar effect. Following irradiation with 1500 rad the greatest depression is observed 7 days after exposure to irradiation. This radiation dose produces also an appreciable decrease in the number of red corpuscles. This depression is not mainly due to an interference with the replacement of erythrocytes which reached their life span but to hemolysis. The life span of the erythrocytes is more than 150 days, thus the daily red corpuscle loss is a very restricted one. Furthermore a marked hemolysis of the tench blood can be achieved by an *in vitro* irradiation with 4000 rad. By decreasing the temperature of the fish to 5° the radiosensitivity of its hemopoiesis very markedly declines. We are at present carrying out experiments at different temperatures to find out if the low radiosensitivity of the fish can be explained by the low temperature at which it is kept alone or if it is partly due to a relatively low cellular oxygen pressure or the presence of protecting agents not present or not present in similar amounts in the bone marrow of mamalia.

The investigation includes also a study of the effect of irradiation on lymphocytes and leucocytes.

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RH 00193
MCHB

"MECHANISM OF THIOL PROTECTION AGAINST RADIATION"

Two of the theories concerning the mode of action of thiols as protective agents against radiation suggest that the thiol acts either by forming a mixed disulfide or by reacting with free radicals formed by the radiation.

We have discovered that sulfinamides readily oxidize thiols to disulfides. This knowledge enables us to test the above two theories concerning the mechanism of protection against radiation by preparing a series of sulfinamides and determining whether they act as protective agents against radiation or as sensitizers to radiation. If thiols exert their protective influence via disulfide formation then sulfinamides would show some degree of protective action as a result of their reaction with natural thiol groups. On the other hand, if thiols protect by reaction with free radicals, sulfinamides will destroy any thiols present and thus act as sensitizers to radiation.

We are currently in the process of preparing a number of sulfinamides for testing for antiradiation activity. Compounds of the type RSONNR are being prepared in which the R groups are aromatic and contain various substituents. It is of special interest to prepare compounds containing amino groups, since in these compounds possible difficulties due to cell permeabilities will be reduced. In the future compounds will be prepared in which one or both of the R groups are aliphatic.

Sulfinamides of the type RSONMR are being prepared by the reaction of Grignard reagents, RMgX, with N-sulfinylamines, RNSO. It is planned to prepare some cyclic sulfinamides by the Diels-Alder reaction of N-sulfinylamines with dienes.

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RH 00203
RAD

"EFFECTS OF X-RAY AND RADIOMIMETIC AGENTS ON LYMPHOCYTES"

The objectives of this program are to study the effects of radiomimetic agents and x-irradiation on nuclear and cytoplasmic amino acid incorporating systems in thymus at early times after treatment. The effects of these agents on these systems will be compared in an attempt to distinguish a similar or dissimilar mode of action of these agents. Initial studies with whole-body x-irradiation or injection of the nitrogen mustard Mustargen, into rabbits indicate that *in vitro* amino acid incorporation by thymus nuclei is inhibited before any inhibition is noted with a ribosomal fraction prepared from the cytoplasmic extract. At later times after treatment, 6 to 8 hours, inhibition is observed with both fractions. Our studies also indicate that one of earliest manifestations of cell damage by these agents is the disruption of nuclear structure of the thymocytes. The presence of DNA is detected in the 5.1P and the microsomal fraction prepared from the cytoplasmic extract from thymus from treated animals. This DNA material is removed from the microsomal fract ion by deoxycholate treatment in preparation of the ribosomal fraction. Labeling of sRNA is not affected in the 5.1P fraction. A colorimetric method for RNA analyses must be used in determination of the specific activity of the sRNA. Studies have been initiated to determine the nature of the DNA material found in the cytoplasmic fractions after treatment. Further attempts will be made to correlate a change in biological activity of the cell fractions at various times after treatment with a change in the chemical and physical properties of any of the components. It is hoped that exploration of the effects of X-ray and alkylating agents in these areas may provide important data concerning the early biochemical lesion in the cell caused by these agents and may contribute to the fundamental problem of the mechanism by which these agents cause cell death.

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RH 00204
RAD

"BIOLOGICAL EFFECTS OF LOW VELOCITY ELECTRONS"

With the widespread interest which has developed in atomic energy, radioactivity, and interplanetary space, radiations of all types have become a factor of prime concern. Much remains to be learned of the action of these radiations on living matter and biochemical systems.

An understanding of the effects of radiations is important in the consideration of such widely diversified fields as interplanetary travel and radiation therapy, to food preservation by electron bombardment.

The researches conducted at the Institutum Divi Thomae deal with the biological and biochemical effects of electrons and, in particular, those of lower velocities ranging between 0 and 1000 volts. This is a field which is extremely difficult to explore due to the fact that low-velocity electrons are so readily absorbed by matter including air. As a result, all tests must be conducted in an extremely high vacuum, that is to say, at extremely low gas pressures.

A unit for testing the effects of these very low-velocity electrons has been developed. Its construction is such that materials to be tested can be conveniently bombarded and specimens readily changed. The electrical circuitry is so arranged that the velocity and number of bombarding electrons (current) can be quickly determined during the course of an experiment.

The apparatus is so constructed that bacteria, viruses, enzymes and other biological and biochemical materials which can withstand extremely low pressures can be readily bombarded.

Results, some of which have been published, and others which are ready for publication, show that electrons with velocities as low as 25 electron volts are lethal to microorganisms. This velocity is critical, i.e., for a given current density there is a spread of but a few volts between good killing and no killing. For example, with an energy of 1.5 watt seconds there is 89.0% killing of Staphylococcus albus at 25 volts, and 0% killing with this same energy density at 20 volts.

RH 00204 (continued)

Earlier investigations using ultraviolet have shown that radiations shorter than 2960 Å are required to kill Staphylococcus albus. This wavelength of ultraviolet corresponds to an energy of 6.5×10^{-12} ergs or approximately 4.2 electron volts. Since the minimum electron velocity with which we were able to observe killing was approximately 25 electron volts, it may be concluded that either the killing action of ultraviolet and electrons is different, or, that the killing action of the two agents takes place in different parts of the cells.

The action of electrons of different velocities on many types of cells, on viruses, enzymes, and many simpler compounds must be studied to obtain basic information on their action. Once sufficient fundamental knowledge is accumulated, the electron should prove a valuable tool for probing the secrets of nature's fundamental unit of life - the cell.

When basic data are available, electrons of accurately controlled velocities could open new avenues for the geneticist, the biologist, and the chemist.

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RH 00206
RAD

"RADIATION EFFECTS IN HETEROGENEOUS SYSTEMS"

The experimental work currently in progress and proposed under this project may be summarized under the following headings:

1) Radiation Effects in Heterogeneous Systems. Surface and interfacial effects in the irradiation of physico-chemical and biological systems constitute an interesting but difficult area for investigation. These are being approached from one direction through a study of Co-60 radiolyses of adsorbed phases of simple organic systems and a comparison of product distributions and yields with those from the homogeneous systems. Adsorption from dilute aqueous solution of simple organic acids on charcoal, for example, significantly protects the material from radiation-induced decomposition.

In the absence of a liquid phase, product yields from adsorbed hydrocarbon molecules are displaced toward lower molecular weights. Evaluation of the actual yield depends upon assumptions concerning energy distribution between the solid and adsorbed phases. Our results are being interpreted in terms of protection of adsorbed species from radical attack and of energy transfer across an adsorbed molecule-solid boundary.

2) Studies in Auto-Radiolyses. Internal beta sources are a versatile tool in studies of radiation induced changes. A system may be studied during the courses of a radiolysis under well-controlled external conditions with a minimum of shielding and, in vessels of reasonable size, with a uniform internal energy density. Current experiments involving S-35 radiolyses in the ferrous and ceric systems have shown temperature dependences markedly different from those in the same systems under Co-60 gamma radiolysis. G(Fe^{+3}), for example, increases by approximately 0.1% per degree with Co-60 as the radiation source. With S-35 in millicurie quantities as the internally dissolved source, the ferric yield decreases at a rate very close to 1% per degree. Our results are being interpreted in the framework of track effects resulting from the differences in the LET values for the different radiations. Our experiments are being extended to other beta emitters and to other aqueous and heterogeneous systems.

3) Radiolyses in Alkali-Halide Pressed Discs. Infra-red spectra of organic solids "dissolved" in a matrix of sodium bromide or iodide are being examined before and after gamma irradiation. Since the rate of fragment recombination is expected to be much slower in such a solid phase system, we hope to characterize intermediates produced by the radiation. The molecules irradiated include organic peroxides and several "stable" free radicals. Preliminary results suggest that this technique, at least for several systems, will allow the detection of such intermediates. In such a reaction matrix chemical changes would be produced almost entirely by freed electrons and might be quite different from change in which the compound is a solute in a liquid medium.

In parallel experiments we have studied color center production in pressed discs in the absence of solute. "F" and "V" centers are produced at 32°C which are similar to those produced in singly grown crystals. We hope to correlate color center formation in the presence and absence of solute with extent of chemical change.

When irradiated alkali halides are dissolved in solutions containing dissolved luminal an intense chemiluminescence is produced which rapidly decays but is detectable after the sample is completely dissolved. We are investigating this phenomenon as a possible tool in measurements of energy storage in irradiated solids.

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RH 00207
RAD

"ANALYSIS OF CHILDREN RADIATED EARLY IN FETAL LIFE"

In 1948 and 1949, each woman who was to bear her first child at our hospital had diagnostic pelvimetry as part of her prenatal check-up early in pregnancy. 1002 children from these pregnancies were involved. Fortunately, at that time, the exposure dose was measured and the calculated dose to the unborn fetus was between 3 and 10 rads. Since this study was part of a more extensive program extending over several years, detailed prenatal delivery and postnatal records are available.

The year before this study and the year after, very little diagnostic X-ray was used during pregnancy. We are currently investigating the radiated children as well as a control group selected from the year before and the year after for the incidence of birth defects, tumors, mental problems and other congenital anomalies. The total population consists of 3006 children.

Thus far we have contacted in a random fashion over 1600 children and find our follow-up 93% effective. The data obtained by mail and telephone follow-up as well as the pediatric record, the birth record and prenatal record are being placed on IBM punch cards for computer analysis.

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RH 00210
HUE

"NEOPLASMS IN CHILDREN TREATED WITH X-RAYS"

The following epidemiological studies of populations exposed to ionizing radiation are being conducted by the Division of Experimental Radiology at the University of Rochester School of Medicine under grant RH 00210-02.

1. Children Treated with X-rays in Infancy for Thymic Enlargement. For the past ten years a periodic mail survey has been conducted to determine the health of 2,809 children so treated and their 4,329 untreated siblings. The results of the 1959-60 survey showing an increased incidence of neoplastic disease (particularly of the thyroid gland) were published in the JNCI (December 1963). The most recent survey has just been completed and the data are being analyzed. Because 472 children in two subgroups treated anteriorly and posteriorly show the highest risk of developing tumors, as many as

possible will be called in for examination. To date, about 100 treated groups shows a surprising incidence of multinodular goiters but no evidence of immunological disturbance characteristic of severe damage to the thymus in infancy. Data from future surveys will be pooled with data from similar studies done elsewhere.

2. Children and Young Adolescents Treated with X-rays or Radium for Lymphoid Hyperplasia of the Nasopharynx. The results of a recent survey of 1,359 children treated with X-rays and radium are being analyzed. A few cases of thyroid cancer and salivary gland tumors have occurred in the treated group. There is no evidence of hypothyroidism as indicated by crude height and weight measurements. In the future, those individuals receiving the highest radiation doses to the region of the sella tursica will be called in for examination and the mail survey will be repeated.

3. Miscellaneous Groups Exposed to X-rays. A group of 660 women treated with X-rays for acute postpartum mastitis has been surveyed and the tumor incidence is being analyzed. Another group of 300-400 children and young adults given X-ray treatments to the region of the neck has been traced and will be queried by mail.

4. Leukemia Incidence in Multiple Blood Donors. Since there are theoretical reasons for believing that repeated stimulation of the blood-forming tissues may increase the incidence of leukemia, the names of approximately 10,000 multiple blood donors (one gallon or more) have been obtained from the American Red Cross. The names and identifying information punched on cards will be matched against the leukemia records of the New York State Department of Health in Albany.

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RH 00218
RAD

"β-IRRADIATION EFFECTS ON DERMAL VASCULAR PERMEABILITY"

The histopathology of irradiated skin is well documented, but there are few reports on radiation-induced biochemical lesions in this complex tissue or its outermost layer, the epidermis. Our earlier studies revealed a diphasic increase in total free amino acid content of guinea pig epidermis after a single contact dose of 3000 rep β-irradiation to the skin from a Sr^{90}-Y^{90} sealed source. (Radiation Res. 11, 684,1959). It was demonstrated by ion exchange chromatography that 18 free amino acids are normally present in guinea pig epidermis and 15 days post-irradiation all 18 increased in concentration, but their pattern (umole % of each) remained unaltered. Recently, similar results were obtained at the 1, 3 and 6 day time intervals. The first peak increase in amino acids occurred about the 3rd day - before any detectable histologic changes or clinical signs of injury. The 18 free amino acids present in epidermis have also been identified in guinea pig plasma. The question arises, is the elevated level of epidermal amino acids the result of increased permeability of the cutaneous blood vessels (β-radiation from Sr^{90}-Y^{90} penetrates into the dermis) or are they products of epidermal cell turnover and keratinization? In order to answer this question, experiments have been designed to study the rate of release of circulating C^{14} labeled nonmetabolizable amino acids into untreated and irradiated epidermis.

In addition, circulating I^{131} - labeled protein will be utilized to determine whether an alteration in vascular permeability can also account for the observed rise in activity of ribonuclease (RNase) (Radiation Res. 15, 785, 1961) and deoxyribtonuclease I (DNase) of irradiated epidermis (J. Invest. Dermatol., June, 1964).

In another approach, Bradykinin, which is known to increase vascular permeability, will be injected intradermally and the changes in concentration of epidermal free amino acids, RNase and DNase I will be followed.

It is hoped that some of the information obtained from these experiments will serve as the basis for a sensitive biological dosimetry test.

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RH 00221
BIO

"PHOTOENZYMIC REPAIR OF RADIATION-DAMAGED NUCLEIC ACID"

The object of inquiry is the photoenzymatic reaction which will repair ultraviolet damage to transforming DNA during its photoreactivation *in vitro* (thereby restoring biological activity) and the relationship of this reaction to recovery processes in intact cells. This encompasses:

1) The attempt to obtain from irradiated polydeoxynucleotides the smallest possible atomic grouping which will serve as a substrate for the yeast photoreactivating enzyme, analogous to the UV-generated lesions in DNA. In order to behave the same as UV damage in DNA, this grouping must combine with the enzyme to form a stable complex in the dark and dissociate from it in the light, while undergoing some alteration itself, to release the enzyme in active form. Such a substrate should permit studies of the mechanism of the photenzymatic reaction. Criteria for recognizing a substrate are provided by the competitive inhibition of transforming DNA repair which occurs when extraneous substrate (not associated with the irradiated transforming DNA) is present in the same reaction mixture (1), and by the stabilization of the enzyme against inactivation which is observed when it is complexed with its substrate in the dark (2). In each case the competing or protecting substrate can be eliminated by a preliminary illuminated with the enzyme before testing (therefore removing the substrate) but not by incubation with it in the dark.

2) The intracellular repair of UV damage to cellular DNA of non-transforming species---damage being assayed (after extracting the DNA from the cells) by the methods described above (3).

3) Detailed comparison of the removal of DNA damage during *in vitro* photoreactivation as indicated by these methods and by the "UV dose reduction" in transforming DNA for any evidence of differences in the biologically inactivating DNA damage and the bulk of the UV-generated substrate in DNA on which the enzyme acts.

4) The possible influence of dark repair processes inside bacterial cells undergoing transformation by DNA on the assay of the UV damage.

RH 00221 (continued)

Recent evidence of such repair processes in Haemophilus influenzae cells (4) makes it uncertain whether the effects studied by manipulating DNA in vitro and subsequently assaying by transformation are due to the bulk of the biologically significant UV damage initially present in vitro or only to a minor part "leftover" after uncontrolled repair processes during the assay have done their best to erase it. Inhibitors of the repair function in H. influenzae assist in this study, but their effect on various parts of the transformation process presently complicates interpretation.

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RH 00224
RAD

(Formerly
RH 00107)

"CHEMICAL MODIFICATION OF REGIONAL RADIATION REACTION, A PRELIMINARY STUDY"

Preliminary experiments were conducted to study the question of whether the chemical radioprotective agent, 2-amino-ethylisothiuronium (AET) alone, hypoxia alone, and in combination with each other, would be useful in modifying the effects of x-irradiation directed to certain sites. The initial region to be studied was bone growth, and the preliminary studies were directed in 3 general areas: 1) Dosage schedules of AET tolerated by the albino (Sprague-Dawley) male rat; 2) Techniques for a) positioning, b) immobilizing, and c) the technical radiographic exposure factors; and 3) various types of occlusive tourniquets to create hypoxia of a hind extremity. Data on AET tolerance, technical radiographic factors, and a series of normal hind limb bone growth curves for growing rats were obtained beginning with weanling animals.

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RH 00222
MET

"STUDIES OF RADIOSTRONTIUM METABOLISM AND REMOVAL IN MAN"

Several approaches are being used for the removal of radiostrontium from man in which the relatively short-lived radioisotope Sr-85 is used as an indicator for the metabolism of Sr-90. In line with previous observations made in this laboratory, agents are being used which increase the excretion of urinary calcium, since the induced excess calciuria was found to be accompanied by enhancement of urinary Sr-85 excretion. A variety of agents affecting calcium metabolism are used alone and in combination by the intravenous and oral route, for instance, magnesium, corticosteroids, parathyroid hormone, sodium citrate, sodium sulfate, stable strontium and certain chelating agents. The effect of these agents on the removal of radiostrontium are investigated at the time of exposure and at certain time intervals thereafter. The effect of different phosphorus intake levels on Sr-85 excretion has been investigated in many during different dietary calcium levls. The data obtained in this study are being analyzed at present. Different corticosteroids having different effects on calcium metabolism have been investigated. A parallelism between calcium and strontium metabolism was noted: corticosteroids which led to increased urinary calcium excretion induced enhancement of Sr-85 excretion while those corticosteroids which did not induce excess calciuria did not result in enhancement of Sr-85 excretion. The combined use of ammonium chloride and mercuhydrin has been investigated on the enchancement of Sr-85 excretion. Orally administered ammonium chloride increased urinary Sr-85 excretion markedly; mercuhydrin also resulted in excess Sr-85 excretion. However, the simultaneous use of both agents was not more effective than ammonium chloride alone. The comparative secretion of Sr-85 and Ca-47 in saliva is being studied in man. The secretion of Sr-85 was found to be very low in comparison to the Sr-85 excretion in urine. The concentration of Sr-85 in other body secretions will also be determined, for instance, in gastric and intestinal juice, in order to gain more information on the distribution of this radioisotope in the body and to study methods which may enhance the excretions of Sr-85 by this route. The decrease in radiostrontium body burden induced by some of the enchancing agents used in man and its mechanism are being determined at present.

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RH 00238
PC

"FATTY ACID HYDROPEROXIDES IN RADIOBIOLOGY"

The aim of this investigation is to provide conclusive evidence as to whether unsaturated fatty acid hydroperoxides are formed in tissues as a result of ionizing radiation. While a considerable body of circumstantial evidence exists which implicates organic peroxides, especially unsaturated fatty acid hydroperoxides, in the etiology of radiation injury to biological systems, it has by no means been so proven. In fact, the presence or absence of such peroxides in irradiated tissues has not been firmly established, largely due to the lack of specificity of current methods of detection (Radiation Research, Supplement 3, 1963).

The rationale of this approach to the problem is that the needed test system, having the required specificity and sensitivity, exists in the phenomenon of the effect of substrate-hydroperoxide upon the induction period of the lipoxidase-catalyzed peroxidation of its substrates, *viz*., linoleic, linolenic, and arachidonic acids. These are the biological compounds having the greatest propensity to form hydroperoxides and are the prime suspects in the indirect action theory of radiation damage. Haining and Axelrod (J. Biol. Che., *232*, 193, 1958) have shown that this characteristic lag phase or induction period observed for the lipoxidase-reaction is shortened by the addition of extremely small amounts of the product of the reaction, *i.e.*, substrate hydroperoxide, to the system. It was further noted that of a number of peroxidic compounds tested, including hydrogen peroxide, only substrate hydroperoxides were capable of exerting the effect. It has subsequently been found in this laboratory that the duration of the induction period is inversely proportional to the amount of substrate hydroperoxide added initially, thus constituting a highly specific and extremely sensitive assay for these compounds.

The specific aims of this study are therefore to adapt this phenomenon as a test for these specific hydroperoxides in lipid extracts of animal tissues and to apply the perfected test to similar extracts of irradiated animals in order to conclusively establish whether or not such compounds are formed as the result of exposure to ionizing radiation. Should an affirmative answer be obtained, the method will be employed to extensively study the conditions for and mechanism by which the process takes place postirradiation and the role of such compounds in radiation injury.

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RH 00239
RAD

"RADIATION PROTECTION AND RECOVERY IN GERMFREE ANIMALS"

Germfree animals are being used in this project 1) to study radiation pathology in the absence of complications from microorganisms; 2) to determine the effectiveness and mechanisms of radioprotective agents under germfree conditions; and 3) to investigate treatment. especially with bone marrow transplants, without the threats of postirradiation infections that obscure and alter results.

Germfree mice have a greater resistance to wholebody x-irradiation than conventional mice. The LD_{50} x-ray dose for germfree Swiss-Webster mice is 705 r; that for conventional mice is 660 r. A more impressive difference lies in the survival times of germfree and conventional mice that die within 30 days after irradiation. Germfree mice exposed to supralethal x-irradiation live a longer time than their conventional counterparts -- 12 days at 1000r and 7 days at 3000 r for the germfree as compared to 3-4 days for conventional mice in this dose range. In an effort to find an explanation for this difference, comparative hematological and intestinal studies were conducted. The principal hematological differences shown by germfree mice as compared to conventional mice were: 1) 10% lower counts of total WBC's, lymphocytes, reticulocytes, and hematocrits in nonirradiated controls: 2) very little difference in radiosensitivity of lymphocytes; 3) no significant difference in hematology at 100 r: 4) a less severe and less rapid depression of neutrophiles at 300 r and doses above; 5) a lesser degree of anemia at 710 r and a slower development of anemia at 850 r; 6) a lesser reduction in platelets at 710 r and a shower decline in platelets at 850 r. Using tritiated thymidine labelling of crypt cells in the intestinal tract, it was demonstrated that the average life span of mucosal cells in germfree mice is longer (5.1 days) than that in conventional mice (2.6 days) and that after 3000 r the intestine of germfree mice was denuded of mucosa in 7 days compared to 3 days in the conventional mice.

Escherichia coli endotoxin has been used in protection studies. The LD_{50} x-ray dose for germfree CFW mice inoculated with 10 ug endotoxin 24 hours prior to irradiation is 950 r; for conventional mice, 850 r.

RH 00239 (continued)

It was determined that endotoxin injection results in a reduction of pO_2 levels in mouse tissues to levels associated with radioprotection (20 mm Hg). The lowest values are recorded 24 hours after injection. In another series of experiments involving protection, the effects of hypothermia and hypoxia were separated -- low pO_2 rather than low temperature is more important in radioprotection.

In bone marrow transplant treatment of irradiated mice, CFW and C3H mice were used. With intracardial injection of bone marrow, the LD_{50} x-ray dose was raised to 1300-1500 r for both isologous and homologous transplants. Secondary disease does occur in germfree mice.

Among current and planned projects are: 1) a pathological study to determine how bacteria alter the response of the hemopoietic and intestinal tissues to wholebody irradiation; 2) an investigation of the mechanism of pO_2 reduction induced by endotoxin; 3) pO_2 studies with other protective agents; and 4) a description of secondary disease in germfree mice.

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"EFFECTS OF C-14 ON CYTOGENETICS"

Since carbon is ubiquitous in living matter, the increase in C^{14} available in the biosphere is a matter of considerable importance. The irradiation (and transmutation to nitrogen) which may occur in C^{14}-containing DNA of germinal cell nuclei may produce deleterious genetic changes of varying severity for generations to come. Therefore, a study of the effects of C^{14} on spermatogenesis in mice which will breathe $C^{14}O_2$ chronically has been undertaken. It is known that C^{14} administered as the carbonate or breathed acutely as $C^{14}O_2$ is lost via the lungs with great rapidity, about 2% being fixed in the tissues. Presumably all the $C^{14}O_2$ inhaled at very low concentrations would be cleared but only 2% retained. Approximately 0.74 uc of C^{14} evenly distributed in a 20 g mouse will yield 0.1 rad/g in one day, which dose is the estimated 30-year male human gonadal dose from background. If a system is arranged wherein a mouse is exposed to an atmosphere in which the concentration of $C^{14}O_2$ remains constant and supplies 0.74 uc/day, and if the animal continues to fix C^{14} at 2% of that available each day, then in 50 days it will have fixed 0.74 uc. The integrated radiation dose will have been achieved in

RH 00243 (continued)

something under 10 days, so that the actual exposure time need be no longer than this. If $C^{14}O_2$ is supplied at the rate of 0.0005 uc/minute, 0.72 uc/day is provided. Up to 50 mice can be kept in such an environment, and once equilibrium is established, sufficient C^{14} will be available for all to reach 0.1 rad dose in 10 days or less. Two Plexiglas constant environment chambers have been built with controls to maintain a temperature of 72° and 45% relative humidity. An evacuable air lock system is provided on the $C^{14}O_2$ chamber; none is necessary on the control chamber. The $C^{14}{}_{02}$ or $C^{12}O_2$ gas, under pressure, will be fed into separate air lines through solenoid valves which will close in the event of a power or air exhaust system failure or if the pressure or temperature in either chamber exceeds safe limits. An electric clock in the valve circuit will indicate any cessation of gas flow which might occur. In operation, 32 l/min. of warmed, humidified air will be mixed with either 0.5 ml natural CO_2 or 0.5 ml of natural CO_2 contaminated with 5×10^{-4} uc $C^{14}O_2$ and be pumped to the respective chambers through flow meters. The concentration of CO_2 in the input air will be increased by less than 4%. The air will be distributed in the chambers and then leave through other flow meters and pass through triple (alkaline) CO_2 absorption towers and thence to the room air exhaust. A complete air exchange will occur every 10 minutes, assuring adequate fresh air and evacuation of metabolic CO_2 and urinary ammonia. When equilibrium is established, the $C^{14}O_2$ concentration may rise due to metabolized C^{14}, and adjustment of input $C^{14}O_2$ may be required. Metabolism cages will be used so that the C^{14} content of urine and feces may be determined. Total CO_2 content of chamber air will be measured by infra red methods, and C^{14} in air or tissues will be determined by liquid scintillation counting techniques.

It is expected that the estimation of radiation dose distribution in the tissues will be very difficult due to nonuniform distribution of C^{14}, but it is thought that by using radioautography and liquid scintillation counting reasonable estimates will be possible, at least for small parts of individual testes.

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RH 00245
RAD

"REDUCED FLAVIN OXIDATION IN PRIMARY RADIATION DAMAGE"

The starting point of the current research is the observation that the bacterial luciferase (light-producing) reaction, both *in vivo* and *in vitro*, is markedly suppressed by x-irradiation, but only while the reaction is being exposed. This suggests that one or more intermediates formed during the course of this complicated reaction are extraordinarily sensitive to the oxidizing free radicals produced in the aqueous phase of the irradiated system. Most of the various individual reactions of which the overall luciferase reaction is comprised have been tested individually, and the one that turns out to be rate-limiting is the DPNH-FMN transhydrogenase reaction. The components of the reaction by themselves are not radiosensitive, and the rate of the reaction resumes its pre-irradiation level immediately after cessation of the exposure.

Since this reaction is common to a wide variety of DPNH-dehydrogenase reactions occurring in every living cell, it occurred to us that use of DPNH, or some combination of DPN and reducing substances, might offer a new method of chemical protection of animals from acute exposure. DPNH itself turned out to aggravate rather than lessen radiation injury, but DPN plus cysteine proved extremely effective. Carr at Kansas U. just reported at the Federation meetings that DPNH increases the oxygen-sensitivity of dehydrogenases, which may be one explanation of the oxygen effect in radiation biology, as well as of our observations.

We are also extending our observations of biological phenomena "under the beam" to the measurement of oxygen uptake in addition to light production of intact luminous bacterial cells. We have noted that immediately upon exposure of cell suspensions to x-irradiation, oxygen consumption by the cells increases, and immediately upon cessation of exposure, the preirradiation rate is resumed. This indicates that radiation renders cell components considerabley more reactive to oxygen than is the case with non-irradiated cells. In continuing our work, we plan to 1) survey other DPNH dehydrogenases for their sensitivity to radiation while actively catalyzing oxidation-reduction reactions, 20 obtain more detail on the effectiveness of DPN with or without reducing agents in radiation protection, and 30 obtain more detail on the radiation-induced increase in oxygen consumption by cells while they are being exposed to radiation.

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RH 00253
RAD

"MEASUREMENT OF NEUTRON SPECTRA IN BIOLOGICAL SHIELDS"

This project is an attempt to measure spatially-dependent neutron spectra in the 1.0 to 12.0 mev region in biological shielding materials. Measurements will be made using a relatively cheap and mobile proton recoil neutron telescope capable of energy resolution in the range of 10% to 15%. The telescope is intended to be appropriate for high neutron flux-high flux measurements near research reactor cores.

The program falls into two parts: first, the design, construction and testing of the telescope; and second, the measurement of spectra in the reactor pool of the Ford Nuclear Reactor. The first part of this program is well underway. A two-detector solid state telescope has been developed, using silicon surface barrier diode detectors. Fast neutrons eject forward protons from a thin polyethylene radiator; these pass through the first detector and stop in the second detector. The resulting ionization pulses are used in fast coincidence to define the proton direction and reduce background counts. Particularly significant has been the development of a low noise 30-micron thin $\frac{dE}{dX}$ detector" through which the protons must pass initially. The use of a solid state detector rather than the conventional gas detector greatly enhances the fast coincidence response.

The telescope has been successfully tested on repeated measurements of spectra from plutonium-beryllium neutron sources. These measurements are currently being repeated in a field equivalent to that anticipated near the reactor. An absolute energy calibration and resolution measurement is also planned using monoenergetic neutrons from a (D-D) Van de Graaf source.

The shielding measurements will be made on the swimming pool floor adjacent to the Ford Nuclear Reactor. Neutron collimators, telescope housing, and shield material mountings are under construction. These must be positioned by remote handling devices through 26 feet of pool water. The telescope will initially view the core through a convergent fast neutron collimator which will also serve to define the dose at the detector. An initial series of runs will be made on the spectra through varying thicknesses of water as the first and simplest biological shield. These will probably be followed by

RH 00253 (continued)

measurements on steel slabs fitted with a reentrant hole of variable depth. It is hoped that the water measurements will be accomplished by August, 1964.

Several problems remain to be studied: (1) The long-term stability of the telescope detectors and their continual performance in a high field is not yet known. If the latter effect is severe, a telescope design with angular offset to remove the detectors from the direct collimated field will be necessary. (2) The influence of fast neutron scattering in the collimator walls must be studied analytically to determine the acceptance angle for neutrons entering the telescope. (3) The effect on the coincidence time is not known when the detectors and preamplifiers are positioned remotely from the amplifiers in each counting channel.

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RH 00279
MCHB

"REACTIONS OF ANTI-RADIATION DRUGS"

The basic thesis of this investigation is that the mechanisms of protection given by anti-radiation drugs are related to the structural properties of these molecules. In particular we are interested in the correlation between drug activity, drug properties and the physical properties of these materials. We are measuring oxidative dimerization potentials and basicity constants of these materials. Both these values will correlate reactivity using the oxibase scale. One conclusion that has been drawn from our researches is that the most effective anti-radiation drugs are those which are most easily oxidized, having the larger electrode potential values and the drugs that are most basic. Another conclusion is that the various current theories of drug protection, namely kelation of metals, reduction of sulfur-sulfur bonds, reduction of peroxides and scavanging of free radicals are all correlated with the oxibase scale.

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RH 00258
RAD
(Formerly
RH 00087)

"GONADAL RADIATION DURING DERMATOLOGIC X-RAY THERAPY"

A study was made of the various parameters which might influence ovary dose during conventional dermatologic X-ray therapy. These parameters included x-ray quality, tube current (ma), beam collimation and field size, shielding, angle of the X-ray beam in relation to the ovaries, and proximity of treatment site to the ovaries.

Ovarian dose was measured during irradiation of the face, upper chest, and back of a specially constructed pressed wood phantom using each of the parameters alone and then in various combinations. The results are presented in tables and graphs.

Because of the many body skin sites which may require therapy, it is impractical to outline the individual precautionary measures which must be taken for each exposure. The principles involved are demonstrated by the results of the various parameters which were studied. In order to minimize ovary dose during dermatologic X-ray therapy, one should utilize lower tube voltage, softer radiation, appropriate collimation, effective shielding minimizing area of field irradiated with no added filtration, increased distance between the X-ray beam axis and the ovaries and angling on the X-ray tube away from the ovaries.

The gonad dose can best be reduced by exerting all of these simple and inexpensive means every time dermatologic radiation is administered. Such precautions will greatly reduce the hazards of error and damage through the use of x-radiation.

Ovarian and testicular doses of gamma radiation derived from the external application of thorium-x, as used for the treatment of nevus flammeus in infants and children has also been under study. For this purpose, a specially constructed, infant sized, pressed wood phantom has been used together with appropriate measuring devices. The study is still in progress.

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RH 00268
RAD

"LOCAL CHEMICAL RADIATION PROTECTION IN MICE"

Local irradiation of the head, with relatively moderate doses, causes death in laboratory animals. Previous studies in this laboratory have revealed that a specific, consistant ulceration of the posterior dorsum of the tongue developes in locally irradiated mice; the mucosa of the remainder of the tongue, although altered, remains intact. This lesion apparently inhibits ingestion thus leading to starvation and dehydration. All other findings in these animals such as weight loss and organ changes, are consistent with such a manner of death. Subsequent studies, in which indwelling gastrostomy tubes were utilized to feed animals after head irradiation and oral radiation death was prevented, indicated that the oral changes are related to the death mechanism.

The main purpose of this project is to study the effect of topical application of chemical radiation protective agents to the tongue mucosa of mice which would subsequently be locally irradiated with doses ordinarily producing oral radiation death. This will be done in a manner to show if the topical application of radiation protection chemicals inhibit or decrease the degree of lingual ulceration.

Studies in this laboratory have already demonstrated that the intraperitoneal administration of three chemical radiation protection agents do produce an appreciable dose reduction factor in the case of local head irradiation. Histologic examination of the irradiated tongues in mice treated with protective chemicals showed that the lingual ulceration was prevented or dimished in degree as compared to the lingual ulceration found in non-treated irradiated mice. Preliminary studies, employing the topical application of these same protective chemicals have suggested an appreciable mortality dose reduction factor indicating that the mode of action of the chemicals apparently can be on a localized tissue or cellular level. Presently these studies are being elaborated and other studies are being conducted to establish the rate of cell population change in the dorsum of the mouse's tongue; and the relation of topical application and irradiation to changing cell population rate.

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RH 00272
RAD

"THE AGE FACTOR IN RADIATION SENSITIVITY OF MAMMALS"

The direct purpose of the experiment is to determine quantitatively: a) the long-term effects of a single whole-body dose of radiation in mice exposed at a specified age, b) the degree of protection against these effects obtained when the mice are exposed under hypoxia. The radiation source used is a 15 MeV linear accelerator, and the mouse strain SAS/4.

1. Life-shortening: Data are being analysed from a pilot experiment to test life-shortening in mice exposed at ages 1 day, 1 week and 8 weeks, to doses of 400 R while breathing air, and 400 R and 800 R while breathing nitrogen. Preliminary results indicate some protection by hypoxia against the long-term effect, but further dose groups in air and nitrogen are needed for a quantitative assessment.

2. Pathological studies: Detailed histological studies are now being carried out on tissues from the mice dying in the above experiment. A preliminary analysis of the post-mortem data indicates no protection against some particular modes of death, e.g. leukaemia or tumours of the lung.

3. Radiation sensitivity of lung tissue: The radiation sensitivity of lung tissue, as measured by the development of tumours in the lung, is being tested as a function of X-ray dose, age at exposure, and an added carcinogenic agent, either before or after exposure.

Experiments have been started in which groups of mice, 23 weeks old, were exposed to 500 R of whole-body radiation 12 days before or after receiving an injection of urethane 1 mgm/gm, or of D.M.B.A. 2 ug/gm. This age was chosen since it has been found previously that the incidence of lung tumours increases with dose if the mice are exposed at about that age.

In a second experiment mice of the same age group were exposed to doses of 200 or 500 R of X-rays, as well as to higher doses of urethane (2 mgm/gm). In this way a correlation will be obtained between two doses of ionizing radiations and two doses of a chemical carcinogen.

RH 00272 (continued)

A similar experiment has been carried out on mice 8 weeks old at exposure, using urethane and D.M.B.A. as above, but reducing the radiation dose to 400 R.

4. Radiation sensitivity of the ovary. The sensitivity of the ovary to radiation and the protective effect of nitrogen breathing are being tested following exposure at different ages. 250 female mice at the age of 1 day, were given a whole-body exposure to doses of 75, 150, 325, 400 rads whilst breathing air, or 150, 300, 650 or 800 rads whilst nitrogen breathing for 60 seconds before and during exposure.

The sensitivity to radiation is measured by using the impairment of total reproductive capacity during the mouse life-span as criterion of damage. Data on litter size and sex ratio are also recorded. Preliminary results for the first 200 days after exposure give a nitrogen protection factor at this level of injury of 1.7.

A similar experiment is in progress on female mice irradiated at an age of 4 weeks, when the radiation sensitivity to the whole-body exposure, as well as of the ovary, are relatively high. Thirty mice per group were exposed to 5, 10, 20, 30 rads while breathing air, or to 10, 20, 40 and 60 rads after 28 seconds of nitrogen breathing. An effect is as yet evident only in the higher dose groups.

The mice exposed at 4 weeks of age in this experiment are also used for a histopathological study. A major observation in this age group is that, although the mice are only 1 year old, already some have had to be killed because of large mammary tumours. This is in marked contrast to the results of a previous long-term experiment, when female mice were exposed to higher doses of radiation from 50 to 800 rads. These produced sterility, and no incidence of mammary tumours was seen. Detailed studies of the mammary tumour type, its growth pattern, invasiveness and transplantability, are now being made in relation to ovarian and histopathological changes.

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RH 00280
GM

"EFFECTS OF DRUGS AND RADIATION ON HAIR AND HAIR GROWTH"

Hair matrix cells undergo mitosis at an exceedingly high rate, with each cell dividing every thirteen hours in the mouse. Consequently this organ is exceedingly sensitive to the damaging effects of X-ray irradiation and chemotherapeutic drugs. In recent years our own studies and those from other laboratories have shown that profound atrophic and dystrophic microscopic changes can be induced in actively growing hairs by these agents, and that the percentage of hairs damaged increases almost linearly with dosage. Growing hairs can be utilized effectively, then, as a biological indicator for the study of pharmacological preparations or of certain experimental procedures which modify tissue responses to ionizing radiation.

An increased incidence of hair damage induced by X-rays has been demonstrated in animals given L-triiodothyronine, and some protection has been observed in mice with hypothyroidism induced by the prior administration of radioactive iodide. Significant protection against hair damage has been found following intraperitoneal injection of cysteamine, and the dose reduction factor (1.5) for these studies compares well with that observed by other investigators following potentially lethal whole-body irradiation.

The same experimental method has revealed striking synergistic effects on hair damage induced by radiation after the earlier administration of colchicine or actinomycin D in dosages too small to produce hair damage from the drug alone. Time-dosage relationships have been shown to be critical; synergistic effects are seen only when a sixteen-hour interval separates the administration of colchicin and radiation, and when four-and sixteen-hour intervals follow the injection of actinomycin D. Reversal of the drug-radiation sequence fails to show this effect. Currently a series of over 100 patients with far-advanced inoperable malignancies is being studied for the long-term effects of fractionated radiation therapy combined with the prior administration of intravenous colchicine at each treatment session. Preliminary findings indicate enhanced therapeutic results for some patients with pulmonary and gastrointestinal tract neoplasms; renal tumors, however, have been unresponsive.

RH 00280 (continued)

Other techniques for the detection of radiation-induced damage in growing hairs are now being investigated. Administration of tritium-labeled serine to mice 72 hours after radiation has revealed marked depression of amino acid uptake in growing hairs. A dual label method, utilizing intravenous $Zn^{65}Cl_2$ prior to irradiation and Se^{75}- labeled selenomethionine after treatment, has also shown significant X-ray hair damage in rats as measured by differences in Zn:Se ratios at control and treated sites. Studies are in progress to adapt these techniques to the investigation of tissue and cellular effects of different modalities of ionizing radiation. These will be combined with electron microscopic observations of the sequence of radiation, chemotherapeutic, and combined radiation-chemotherapeutic induced changes, with special attention to mechanisms of cellular injury and cellular recovery processes. Initial joint investigations nave revealed that impaired hair growth rates are a sensitive early measure of chronic whole-body postirradiation changes in mice exposed to small doses of chronic neutron or gamma-ray radiation for periods of 3-4 months. Changes in hair growth rates induced by acute radiation exposures are also being evaluated.

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RH 00294
GEN

"CYTOLOGICAL ANALYSIS OF AGING IN PLANT CELLS"

This project was initiated at Yale University in 1961 when Mrs. Sax found that the frequency of chromosome aberrations, and the sensitivity of the chromosomes to X-rays, increased in human tissue culture cells with the aging of the cultures. It has long been known that the frequency of chromosome aberrations in seeds is increased with aging. Since seeds are easier to work with than tissue cultures the more recent work has been done with seeds at North Carolina State College, Oxford University, University of California, University of Tennessee and the University of Georgia.

It was found that old onion seeds are more sensitive to X-rays than are fresh seeds, as measured by the frequency of induced chromosome aberrations. Physiological aging, as measured by the delay in germination of seeds of the same chronological age, is also correlated with an increase in spontaneous and X-ray induced chromosome aberrations. It has long been known that sub-lethal doses of X-rays shorten the life of both plants and animals, but aging is hastened only near the end of the normal life span. The same trend is found in seeds subjected to low doses of X-rays.

RH 00294 (continued)

During recent years it has been found by investigators at the Oak Ridge National Laboratories and elsewhere that various agents can reduce radiation damage in plant cells and prolong the life of irradiated animals. It occured to us that these agents might slow down the aging process in plants and animals, and especially in seeds.

These protective agents fall into two general catagories: those which promote protein synthesis, and those which reduce the oxygen level in the cell. Onion seeds were soaked in solutions of AET, cysteine and kinetin, all of which promote protein synthesis. Seeds were also soaked in a solution of thiodipropionic acid, an antioxidant. The control seeds were soaked in water. After soaking for 10 to 20 hours the seeds were dried and stored for aging. At intervals the seeds are tested for viability and chromosome aberrations. The first divisions in the root of the germinating seed are used for the determination of chromosome aberrations.

When older seeds are used for the test they already have some spontaneous chromosome aberrations. The work to date indicates that the protective agents do not heal the breaks in the chromosomes which existed when the treatment began. More time is required to determine if the protective agents will prevent or reduce chromosome breaks which lead to the production of chromosome aberrations. Aging of the seeds can be speeded up by storing the seeds at high temperature and high humidity. Some preliminary tests along this line are being done with Drosophila by a colleague at the University of Georgia. Lower concentrations of the chemicals may be necessary since some are toxic at high concentrations.

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RH 00297
MCHB

"RADIOPROTECTIVE BASIC THIOLS"

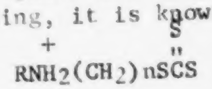
Mercaptans having basic groups (amino or guanidino) located two or three carbon atoms distant have been among the most effective of the agents which protect animals against the lethal effects of ionizing radiation. Two of the mechanisms which have been proposed to explain this protective action are the mixed disulfide hypothesis and the postulation that metal-binding is important. The former mechanism potulates that the protective thiols form mixed disulfides with the thiol groups of proteins, including enzymes, and absorb some of the energy resulting from collision with radiation-produced free radicals or ions in the cells. Metal-binding may operate either for scavenging ions of copper or iron to interrupt harmful cellular oxidations, for stabilization of the cuprous state in cuprous ion-containing enzymes, or for protection of the metal constituents of enzymes from free radical or ionic attack through transient chelation of the metal (still combined with the enzyme by the protective compound).

Evidence has been found in our laboratory to substantiate the latter view. Antiradiation screening carried out at the Walter Reed Army Institute of Research has shown that copper and iron complexes of 2-Mercaptoethylamine (MEA) and 2-mercaptoethyl guanidine (MEG) (prepared in our laboratory) had little or no protective ability, whereas the corresponding zinc complexes were as highly protective as the thiols themselves. This indicates that protection of iron- and copper-containing enzymes is of importance in radioprotection, since the zinc would be easily displaced by copper or iron, metalloenzymes.

The synthesis of derivatives of MEA and MEG containing more reactive thiol functions, which might operate more effectively either for mixed disulfide formation or for metal-binding, is now being undertaken. Some success in this direction has already been achieved. Conversion of MEA to the thiosulfate, or Bunte salt by Holmberg and Sorbo, and to the thiophosphate by Sorbo, has been reported to give compounds with good radioprotective ability. In our laboratory, MEA and MEG have been converted to acyl thio esters and trithiocarbonate zwitterions, both types of compounds showing good protective effects in animals.

RH 00297 (continued)

We are now in the process of synthesizing other potentially "active" thiol compounds. Other trithiocarbonates (I), particularly those having aliphatic chains in the range of six to sixteen carbon atoms to provide a good range of liposolubilities, are being prepared. The preparation of trithiocarbonate bisesters (II) is also being investigated for compounds of the MEA nad MEG type. In regard to metal-binding, it is known that copper salts of trithiocarbonates are stabilized in the cuprous state. Another type of reactive sulfur-containing group under investigation is the sulfenyl thiocyanate (III). Thio acids of the types RCOSH and RCS_2H which contain α-or β-amino groups (IV and V) are also being investigated along with the corresponding imidothiols or imidothioesters (VI). Another variety of active thiolation agent may be found in the aminomethylthiuranes (VII). One proposed method of synthesis of these compounds might provide 1,3-diamino-2-mercaptopropanes (VIII) as well.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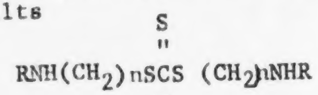
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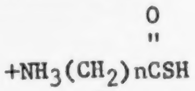
III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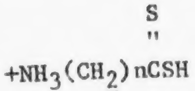
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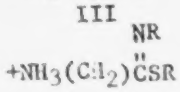
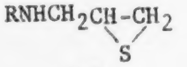
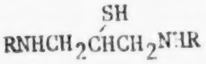
V


$^{+}NH_3(CH_2)\overset{NR}{\overset{\|}{C}}SR$

VI


VII


$RNHCH_2\overset{SH}{C}HCH_2NHR$

VIII

Routine tests for mixed disulfide formation and metal ion complexation will be carried out with all compounds prepared. The Department of Radiobiology at the Walter Reed Army Institute of Research has also agreed to screen our compounds for radiation protection in animals. It is hoped that correlations between protective ability and either of the above tests may be found.

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RH 00300
MCHB

"α-AMINO MERCAPTANS AND α-AMINO SULFIDES"

The purpose of this work is mainly to explore the possibilities of α-amino mercaptans and some of their derivatives for overcoming damaging effects of X-rays and other radiation. β- and α- amino mercaptans are well known to have anti-radiation activity, and γ- and δ- amino mercaptans have been found to be inactive. α-Amino mercaptans, however, have not been previously tested, and it seemed that these might also serve as radical traps, with perhaps fewer toxic reactions than observed with presently available drugs.

The chemistry and biological effects of this class of compounds are little known at present. Two α-amino mercaptans, 1- mercaptomethyl-piperidine and 1- mercaptomethyl-morpholine have been reported by Binz and Pence, J. Am. Chem. Soc., 61, 3134 (1939), utilizing the reaction of secondary amines with formaldehyde and hydrogen sulfide, and we have prepared 5, 5-dimethyl-2-mercaptopyrrolidine hydrochloride and sodium diethylaminomethylmercaptide, utilizing two other approaches, the addition of hydrogen sulfide to imines and the alkali-metal cleavage of α-amino sulfides. We are employing these three methods, as well as examining other possible methods, such as addition of amines to thiones. We are interested in compounds having the amino function in a ring structure, as well as acyclic compounds.

Among the derivatives that we are examining or will examine are thiolesters and Bunte salts. Thiolacetates are found to be readily available by use of thiolacetic acid in place of hydrogen sulfide in the first two methods above and by reaction of the α-aminomercaptide, from the third method, with acetyl chloride. The hydrolysis and rearrangement of α-aminoalkyl thiolacetates is being studied at present.

The effect of structure on properties such as basicity and chelation ability is also under investigation. In this we are studying other types of amino mercaptans and amino sulfides, primarily for comparison purposes. We are also interested in studying the oxidation of α-amino sulfides and the products formed. It seems possible that α-amino oxide sulfoxide and sulfones may have interesting chelating and biological properties. Spectral properties of all compounds will, of course, be observed, and it is anticipated that most of them, if not all, will be submitted for biological testing.

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RH 00303
HUE

"PRENATAL EXPOSURE TO RADIOACTIVE IRON"

The effects of prenatal exposure to radioactive Fe^{59} will be assessed some fifteen years following the exposure in approximately 800 children. These children were born to mothers who attended Vanderbilt University Hospital Obstetric Clinic during the years 1945 through 1949, and who were given radioactive Fe^{59} absorption during pregnancy. A well matched control group of approximately 1500 children, whose mothers received no iron, will be available for comparison. The mothers of these 1500 children also attended the Obstetric Clinic during 1945 to 1949, and along with the iron-fed mothers were part of the larger Vanderbilt Cooperative Study of Maternal and Infant Nutrition. A sibling control group will be utilized to evaluate possible familial non-radiation related influences.

The primary aim of the proposed study will be to determine any increase in incidence of leukemia and other tumors in the children whose mothers received the radioactive iron. At the same time, an attempt will be made to assess any increase in the incidence of congenital malformations in the irradiated groups, plus any effects on growth and general health that may be detectable.

Follow-up of the study population, both irradiated and control groups, will be through telephone or mail questionnaire and when indicated through contact with private physicians. The questionnaire method of follow-up has been used extensively and successfully in studies by Hempelmann and associates. Questionnaires for the present study have been developed using those of Dr. Hempelmann as a model.

An effect from the low doses of irradiation (1 to 15 rad estimated to the fetal marrow) received by our population will undoubtedly be difficult to detect. Thus, it will be necessary to obtain essentially 100% follow-up to be able to evaluate results.

There is little reason to doubt the tumorigenic effect of high (greater than 40 to 100 rad) doses of radiation in humans. The evidence for the effect of low doses is conflicting. Studies of

RH 00303 (continued)

populations irradiated in utero and in infancy have suggested the possibility of enhanced susceptibility of young tissue to irradiation. None of these latter studies have dealt with the effect of internally deposited radionuclides. Aside from the known variation in distribution of dose from internally as opposed to externally delivered radiation, differences in dose rate may be significant. We believe close scrutiny of the present status of our study population will contribute valuable information in an area of considerable scientific interest.

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RH 00305
BIO

"MERCAPTO-DISULFIDE INTERCHANGE IN RADIOPROTECTION"

Cysteamine (2-aminoethanethiol, caSH) affords a measure of protection against radiation injury, and so do a few other related compounds (cysteine, glutathione, 2-aminoethylisothiouronium bromide). Many other mercaptans and amines do not protect, however; some, indeed, are sensitizers, for example, 2-mercaptoethanol (meSH). It is interesting to speculate whether protection from and sensitization toward radiation are obverse aspects of the same general physiological process (es).

The purposes of the present project, which was initiated in January, 1964, is to study some chemical properties of cysteamine, which may be involved in its protective action. So far as possible, it is planned to do similar studies on 2-mercaptoethanol. It is hoped that the parallel study of a protective and of a sensitizing compound will provide interesting comparisons and contrasts.

When administered to living organisms, caSH becomes bound to various tissue proteins, and this may occur by mercaptan-disulfide interchange reactions (let $Pr(S_2)$ represent a disulfide group in a protein):

$$Pr(S_2) + caSH - HSPrSSca$$

It is planned to study the reaction of caSH and MeSH with some proteins and enzymes, to determine the stoichiometry and rate of reaction, and the properties of the resulting protein product.

RH 00305(continued)

Another mercaptan-disulfide interchange which may be important in radioprotection is the reaction with the oxidized glutathione (glSSgl) present in blood and tissues. Some measurements of the equilibrium between (glSSgl) and cysteine have been made, but there is disagreement regarding the results. It is planned to reinvestigate this system, and to extend the study to caSH and meSH:

$$caSH + glSSgl = caSSgl = glSH \quad (1)$$

$$caSH + caSSgl = caSSca = glSH \quad (2)$$

The disulfides which result from equation (2) may interact with the mercapto groups of proteins; e.g., as follows:

$$PrSH + caSSca \rightarrow PrSSca = caSH$$

A study of the reaction of (caSSca) and (meSSme) with some mercapto-containing protein molecules will be undertaken.

Mixed disulfides may be formed in a third way, by oxidation:

$$PrSH + caSH + \tfrac{1}{2}O_2 \rightarrow PrSSca + H_2O$$

This reaction will be studied in mixtures of simple mercaptans and of mercaptan with proteins.

It has been suggested that radiation damages proteins especially at the mercapto and disulfide groups; also, that mixed disulfides formed from a protein and a radioprotective agent may undergo reaction without the protein sustaining irreversible damage; e.g.,

$$PrSSca + H_2O \xrightarrow{radiation} PrSH + (ca, S, OH)$$

In order to test this hypothesis, attempts will be made to prepare modified proteins containing mixed disulfide groupings. The reactions mentioned above may be applied, as well as reaction with such compounds as $CaSSO_3$ and caSCN. Comparative studies of the effect of radiation will then be made.

Synthesis of C^{14}-labelled $caSSO_3$ and caSH will be developed, as it is desired to use these compounds in the studies mentioned above. A review of the literature on the radioprotective and radiosensitizing mercaptans and disulfides is in progress.

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RH 00306
PMY

"CYSTEAMINE AND X-RAYS PRENATALLY: BEHAVIOR OF THE RAT"

Cysteamine as well as other agents have been shown to protect the developing fetus against gross morphological abnormalities due to radiation exposure. As yet, however, there have been no behavioral studies reported on the effects of these agents administered prenatally. In view of the fact that behavioral changes can be induced by prenatal exposure to ionizing radiation even at very low levels, an investigation of the possible protective action of cysteamine against radiation-induced behavioral alterations was begun. Specifically, the aim of this work is to determine whether mental retardation, seizure susceptibility, and diminished motor and sensory ability due to prenatal exposure to X-irradiation can be eliminated or lessened by the use of radioprotective agents.

The dose employed is 100 mg/kg of body weight and the injection will be made intraperitoneally 15 minutes prior to exposure to radiation. Well-filtered 250 KVP X-rays will be administered to pregnant rats at a rate of approximately 20 r per minute in air at doses of 50, 110, and 185 r. The day of gestation selected is day 15 since exposure at this time commonly produces offspring with permanent, but not necessarily lethal, cerebral defects. The role of the pituitary-adrenal system will also be studied by means of irradiating pregnant rats who have been adrenalectomized, since it is known that the fetal adrenals hypertrophy following maternal adrenalectomy which may serve a protective function against radiation damage in the developing organism.

The behavioral measures to be used will include maturation of the upright and righting responses, time to traverse an inclined plane, the Lashley III maze for food reinforcement, the Lashley III water maze, and the audiogenic seizure test.

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RH 00309
HED

"EFFECTS OF IONIZING RADIATION ON MAMMALIAN GAMETES AND ZYGOTES"

(1) Irradiation of rabbit sperms and eggs in vitro. Since it is known that fertilization *per se* is highly radioresistant, although the segmentation of fertilized eggs is severely damaged by irradiation of either sperm or eggs (Chang, et.al. Anat. Rec., 129: 211, 1957; 132: 161, 1958), it is proposed to determine the effects of irradiation at lower dose levels (200, 400, 800, and 1,600 r) of either rabbit sperm or eggs, of both sperm and eggs, on the proportion of eggs fertilized, their rate of cleavage and potentiality for normal development.

Following the insemination of rabbits with normal or irradiated sperm, irradiated or nonirradiated eggs will be transferred into the Fallopian tubes of these animals. They will be examined at: (1) 12-18 hrs. after the transfer to determine the rate of fertilization and the behavior of the pronuclei, (2) 2 to 6 days after transfer for the determination of cleavage rate and blastocyst formation, and (3) at 25 days after transfer for the examination of foetal development.

(2) Irradiation of spermatozoa in the female tract. The relative radiosensitivity of rabbit sperm in the female tract and of eggs at different stages of maturation will be studied by (1) irradiation of rabbits, 4, 6, 9, and 11 hours after mating to determine the effect of irradiation of both sperm and eggs, (2) irradiation of rabbits 4, 6, 9, and 11 hours after LH injection, immediately followed by the insemination of nonirradiated sperm to determine the effect of irradiation of eggs alone at different stage of maturation and (3) irradiation of rabbits when their ovaries are shielded at 4, 6, 9, and 11 hours after mating, to determine the effect of irradiation of sperm in the female tract. The animals will be examined 1, 6, and 25 days later.

(3) Irradiation of maternal organism without the irradiation of embryos.

It is known that irradiation of recipient rabbits without the irradiation of embryos causes the degeneration of embryos (Chang and Hunt, Anat. Rec., 137: 511, 1960), it is planned to irradiate the whole recipient rabbit, only the head of the recipient, or only the lumbo-sacral region of the recipient before the transfer of non-irradiated eggs into these rabbits. These animals will all be examined 25 days after transfer to determine whether the harmful effect of irradiation of the maternal organism is on the hypothalamus and the pituitary; on the ovaries and the uterus, or on the whole body.

Any interesting observations made during this study will be followed intensively to evaluate the effect of irradiation on the germ cells, early embyros, and the reproductive system.

At present, the extreme high radiosensitance of mongolian gerbil (LD/50/30 days: well above 1,000r) is under investigation.

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RH 00311
AI

"IRRADIATION AND MARROW TRANSPLANTATION IN LARGE ANIMALS"

Grant RH 00311 is concerned with studies of whole body irradiation and marrow transplantation in dogs and primates. Current work involves 3 principal areas:

1. Histocompatibility typing. The aim of these studies is that of selection of donor and recipient of reasonable histocompatibility before the act of grafting. In an attempt to develop typing sera, animals are being immunized by injection with whole blood or lymphocytes or by skin grafting. Techniques used in testing for antibodies are leukoagglutination, cytotoxicity and dextran hemagglutination.

2. Pathophysiology of secondary disease. The aim of these studies is that of a better understanding of the secondary syndromes and of their prevention. Current work involves an assessment of immunosuppressive drugs in prevention of parabiotic intoxication in mice and in prevention of secondary disease in dogs after cross-circulation.

3. Support for the irradiated animal. The aim of these studies is that of provision of leukocytes, platelets and other supportive factors needed to keep the irradiated animal alive until an allogeneic marrow graft is effective or until autologous regeneration can occur. Current studies involve cross-circulation in pairs of dogs. Indwelling silastic-teflon shunts have been developed to permit cross circulation without anticoagulation. We are currently studying quantitative transfer of leukocytes between these pairs. We are also assessing the effect of cross-circulation in induction of immune paralysis (or tolerance) by skin grafts between the pairs. Marrow grafts have also been obtained by cross-circulation and additional studies of this type are planned.

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RH 00312
RAD
(Formerly
RH 00094)

"BIOLOGICAL FACTORS AFFECTING RADIOSENSITIVITY OF MICROORGANISMS"

RH 00312-01 is concerned with biological factors affecting the sensitivity of the cells of yeasts and bacteria to inactivation by ionizing radiation. The immediate goal of this project is the elucidation of cell division associated changes in radiosensitivity as exhibited in these organisms. There is reason to believe that there are at least two quite different cellular sites of radiation inactivation and that their relative sensitivities vary during the cell cycle with the result that different mechanisms of inactivation prevail during the different stages of cellular sensitivity. A number of experimental approaches to the testing of this hypothesis are being made; these are as follows:

1) "Suicide" studies with yeast cells in which cellular inactivation is measured as a function of decays of incorporated radioisotope (tritium) in the ribose nucleic acid and deoxyribose nucleic acid. Budding and interdivisional cells which differ markedly in sensitivity and kinetics of X-ray and γ-ray response are being compared. It is expected that the experiment will reveal whether or not the decreased cellular sensitivity of budding cells to radiation inactivation is associated with inactivation of cytoplasmic (or non-DNA-containing) sites.

2) "Physiological" studies of yeast cells in which the radiobiological consequences of alteration of cellular components (viz. as a result of contrasting conditions of preirradiation cultivation) are examined. It is thought that cytoplasmic "sites" might be more maleable to environmental stress than nuclear ones and that a shift in pertinent composition will be expressed as a change in sensitivity of a cell with respect to cytoplasmic inactivation.

3) "Genetic" studies with yeast cells, in which by the mating of appropriately marked strains, (i.e. in both nucleus and cytoplasm) one should be enabled to observe, in the zygotes resulting from otherwise radiation inactivated cells, phenotypes indicative of the sites of inactivation (and resistance) of the gametes. Performed with gametes of contrasting radiation sensitivity this experiment should show whether or not the cytoplasm of radioresistant (i.e. budding) cells could contain the radiosensitive sites.

4) "Recovery" studies with yeast cells in which cells of differing radiosensitivity are assayed for their ability to repair radiation induced lesions. There is reason to believe that different cellular sites of inactivation should be subject to quite different modes of repair of radiation damage. For example, during budding the yeast cell is either "immune" to the induction of recessive lethal damage or repairs such damage prior to assay. Moreover, budding cells surviving "haploidization doses" (doses sufficient to reduce the "target" multiplicity to one, after which survival is exponential) are upon subcultivation restored to original sensitivity and multiplicity. Thus the sublethal damage inflicted by "haploidization" is not hereditary unlike the behavior of diploid interdivisional cells (which also show multi-hit survival) whose "haploidized" survivors give rise to progeny more sensitive than the original cells.

5) Studies of anomalous multi-hit survival curves. Many ostensibly haploid microorganisms show multi-hit inactivation kinetics in response to ionizing radiation (for example certain strains of Chlamydomonas, Aspergillus, Azotobacter agile, Bacillus subtilis). These will be subjected to such "physiological", "genetic", and "recovery" studies, similar to those outlined above with reference to yeast cells, as seem best suited to reveal the site of radiation inactivation.

Many bacteria as well as some higher forms are known to be refractory to mutagenesis by radiation. It seems possible that these represent systems possessing nuclei of significantly greater resistance than the cytoplasm. Also suspect in this light are cellular systems (such as some mammalian cell cultures) which show in their radiation response aberrant ploidy dependence. The confidence with which one can equate cellular sensitivity with nuclear sensitivity might be expected to have practical as well as theoretical value.

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RH 00345
MET
(Formerly
RH 00019)

"PROTEIN METABOLISM IN NORMAL AND IRRADIATED LENSES"

Our present work is concerned with protein metabolism and permeability in normal, irradiated and galactose-cataractous lenses. The permeability of labeled amino acids into irradiated lenses is altered before one can detect any significant inhibition in amino acid incorporation. Twelve hundred roentgens (head irradiation) causes no significant decrease in the rate of C^{14}-leucine incorporation into lens proteins until the lens begins to show changes characteristic of irradiation cataract. These results indicate that the major lens dysfunction is not one of protein synthesis but rather of lens permeability.

Similar experiments were carried out with normal and galactose-cataractous lenses. The data clearly indicate that amino acid penetration is reduced in lenses from animals fed galactose for only 24 hours (no visible sign of cataracts). Lenses from animals fed normal "Purina Chow" diets, high dextrose diets or fasted, showed normal C^{14}-leucine uptake. Amino acid incorporation into proteins was also measured in these lenses and the data were expressed as the per cent of the total lens radioactivity incorporation into lens protein. In these three groups, the lenses incorporated the same percent of the total lens C^{14}-amino acid activity into protein. However at 9 days, lenses from animals fed a high dextrose diet showed significant inhibition in the percent of the total lens radioactivity present in the protein fraction. Thus it appears that lenses from galactose-fed animals are inhibited in their ability to actively transport amino acids, but once the amino acid is in the lens, it is incorporated into lens protein at a normal rate. This occurs even before the onset of the cataract. On the other hand, lenses from the dextrose-fed animals have a normal active transport of amino acids, but there is inhibition in amino acid incorporation into proteins. The fact that lens permeability and protein incorporation can be measured independently has been further confirmed by inhibition studies.

Changes in the concentration of proteolytic enzymes do not seem to be involved in the process of cataractogenesis since proteolytic activity does not change in the precataractous lens. Lens protein catabolism was measured by a new and very sensitive method, i.e. studying the ability of lens homogenates to degrade radioactive insulin. Also the nature of the enzymes involved has been extensively studied (pH, inhibitors, activators, and kinetics). The concentration of proteolytic enzyme in lens varies inversely with age. There is a 50% decrease in concentration for every 20 mg increase in lens weight. Proteolytic enzymes have also been studied utilizing synthetic substrates.

The mechanism of fatty acid transport in the lens and its possible relationship to cataractogenesis was studied employing sodium valerate-1-C^{14}. The transport process is temperature dependent having an optimum temperature of approximately 50°C. and an apparent Q_{10} of 1.7. The transport is inhibited by various metabolic poisons indicating that it is an energy-requiring process. Also the efflux of C^{14}-valerate from equilibrated lenses is inhibited by 2,4-dinitrophenol (suggesting that it too is an energy-requiring process). Metal ions with the exception of the mercuric ion which strongly inhibits, have no apparent effect on the transport. Insulin has no effect on the transport of C^{14}-valerate in the rat lens. Kinetic data indicate that the transport is of the facilitated diffusion type and apparently the same site or carrier serves for entry and exit. The transport process can be driven to become active, that is, against a concentration gradient by eliciting the phenomenon of flow driven by counter flow. The uptake of C^{14}-valerate by galactose-cataractous lenses is increased but this increase is apparently due to an increase in the water content of the lens. The alteration of C^{14}-valerate uptake occurs only after the onset of cataract formation. In irradiated lenses, there is a decrease in C^{14}-valerate uptake. The decrease is possibly associated with a decrease in sulfhydryl groups.

The ability of lens homogenates to degrade riboflavin, FMN and FAD has also been studied. Enzymes are present which can degrade FAD to FMN, but no evidence of a reverse reaction (even with ATP present) has been found. These hydrolytic enzymes have been further characterized. Their concentration does not change significantly with irradiation or with aging.

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II. MEASUREMENT OF RADIATION EXPOSURE

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RH 00003
RAD

"ABSORBED RADIATION DOSE INCIDENT TO FLUOROSCOPIC PROCEDURES"

A determination of radiation exposure of the population as the result of medical X-ray examinations depends upon accurate information of radiation received during a variety of radiologic procedures. In the past most studies have been limited to measurements of radiation exposure to critical organs and selected body segments in radiographic examinations in which radiation factors such as quality and quantity of radiation as well as field size are relatively fixed and not subject to wide variations.

Relatively few studies have concerned themselves with fluoroscopic radiation exposure which is much more difficult to determine because of continuous variations in field sizes and rapid and frequent changes in the position of the X-ray beam in relation to the human body.

The present project has approached the solution of this problem by the development of special fluoroscopic recording and simulating equipment.

During actual clinical radiologic examinations a continuous and permanent record of X-ray tube position, beam area, patient position, and exposure time is made on punch paper tape utilizing the recording system developed in this laboratory.

The patient identification, age, weight and height, type of examination, physician identification, and X-ray machine parameters are recorded by an attending technician. The resulting data is evaluated in two ways:

1. A punched paper tape record produced by the recorder is used to control a fluoroscopic simulator developed specifically for this application. The simulator duplicates the original fluoroscopic examination as performed by the radiologist. A tissue-equivalent phantom placed on the simulator table is exposed to the X-ray beam in the same way as the patient was during the original examination. Radiation exposure to selected body segments and critical organs, such as ovaries, bone-marrow and spleen is then measured with small tissue-equivalent ionization chambers placed within the phantom to provide determinations of radiation dose to critical organs.

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2. The basic data is also processed by a UNIVAC Solid-State 90 computer. From the recorded paper tape of each examination the computer is programmed to calculate and print out the following:

   a. The average surface exposure area.
   b. The total exposure time.
   c. A topo-anatomical graphic display exposure pattern.
   d. The distribution of exposed areas.
   e. The integrated surface exposure. This term is a quantity which expresses the total X-ray energy imparted to the patient. It is computed by multiplying the exposure area for each one-second time interval by the X-ray machine output (in roentgens per second) of the fluoroscopic examination. The surface exposure interval has the units of roentgens square centimeters. From the determined surface exposure integral the integral dose can be calculated.

The above results and the critical organ exposure from the simulation measurements are recorded on a single standard punched card with the patient identification, physical characteristics, and type of examination. These cards are used by the computer for tabulation and correlation of the various exposure parameters for each kind of examination.

Approximately 1000 fluoroscopic examinations performed by fifteen (15) different doctors with various levels of training and experience at Emory University Hospital are under study. These will be increased to well over 2500 by the end of 1964 and will include a large number of cases from another University affiliated hospital.

Through graphic representation of the recorded beam area and exposure time for each second of the fluoroscopic procedure, it is possible to make useful comparisons of the techniques used by radiologists in various levels of training when performing similar fluoroscopic examinations. These data also provide comparisons of the exposures resulting from the use of different X-ray technique factors such as occur with the use of image amplification.

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RH 00030
ESE

"ENVIRONMENTAL EFFECTS ON THE CONTENT OF CESIUM^{137} IN MILK"

Fifty-five dairy farms, selected to cover the major environments within the agricultural area of Utah, are being intensively studied to determine what factors of the environment affect the accumulation of Sr-90 and Cs-137 in crops, milk, and people. The test is designed to show effects of altitude, meteorological factors, geographic location, topographic effects, soils, water, farming practices, and time on the accumulation of fallout radionuclides.

Several factors reported to have caused changes in uptake of Cs-137 and Sr-90 by plants grown in soils under laboratory conditions are being studied in the field. This involves soil relationships including choices of farms to give differences in great soil types (sierozems to chernozems), soil porosity (sands to clays), soil humus, soil nutrients, pH, micronutrients, and water-holding capacity. Water handling procedures which affect the amount of water in the soils or cause periodic or permanent flooding receive special attention

Dairy farms have been selected for contrasting ecological conditions, with a pair or group of four to eight stations situated close together to minimize differences in fallout rates, Within groups, each station has been chosen to contrast in some ecological factor with all of the other stations. Groups and pairs have been placed in the following areas: Cache Valley, Salt Lake Valley, Summit County (Norther Highlands), Uinta Basin, Colorado Basin, Wayne County (Southern Highlands), Great Basin, and Virgin River Drainage. The several groups embrace all the major climatic zones in which farming is done and most of the dairy sections of the state. Mean annual yields of radionuclides for each group of stations is compared with the other groups to show regional differences attributable to cumulative ecological factors rather than individual farms.

Gamma-emitting nuclides in milk, vegetation, soils, and humans, are determined with a 400-channel analyzer and an NaI (Tl) 8" x 4" crystal. Humans are counted in a low-background chamber, and milk, vegetation, and soils are counted without ashing in plastic containers.

Strontium-90 is determined by radiochemical methods by the Eberline Instrument Company of Santa Fe, New Mexico.

RH 00030 (continued)

Human ecological studies including whole-body counting of people from the separate dairy farms and selected areas of Salt Lake City is an important phase. People are counted at least twice a year and studies of foods used by each family with special attention to quantities of milk consumed by each person are underway. Accumulation rates in people from the farms are contrasted with those of people from Salt Lake City who obtain milk from many sources.

Limited studies of wildlife and livestock grazing areas adjacent to the dairy farms are being done with the objective of determining rates at which fallout nuclides accumulate in these organisms and to see whether wildlife follow the regional patterns shown by the groups of dairy farms.

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"BACKGROUND RADIATION IN FLORIDA"

Following preliminary investigation, the Florida State Board of Health in November 1962 began a study of background radiation exposure in Florida. Equipment was procured and set up and personnel recruited and trained. Following a review of population distribution and of geological information indicating the likelihood of high or low background radiation, and after pilot studies, the Florida phosphate region was designated for initial intensive study and other sampling and measurement locations were selected. As of December 31, 1963, 723 measurements of external gamma radiation were made with a portable scintillation survey meter. Elevated levels were found due primarily to monazite and phosphate deposits but readings were quite variable, apparently depending on proximity of the active deposits to the surface. Soil samples are being submitted to gamma spectrometry in order to develop a procedure for distinguishing between fallout and natural sources of radiation exposure. A program of sampling air for natural radioactivity was begun at two stations. One hundred and eighty-five samples have been collected and analyzed for morning radon activity, afternoon radon activity, soil activity and long-lived activity. Average concentrations at one station were about 3½ times those at the other. Thoron concentrations show little difference between the two stations. Gross alpha analyses are being performed on water, milk and food samples the study area for comparison with state-wide samples. As the project proceeds, data will be reviewed and measurements and sampling will be modified and continued as indicated. The work currently being done is the initial phase of a long range study which should provide additional information about the effects of low levels of radiation exposure to the population.

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RH 00085
RAD

"DOSE DISTRIBUTIONS IN DIAGNOSTIC X-RAY PROCEDURES"

During the past seven years, this laboratory has devoted major effort to a comprehensive study of the dosimetry of diagnositc radiology. It has been the objective of this investigation to evaluate quantitatively the influence of a broad range of physical and anthropometric factors on the radiation doses received by the tissues of individuals undergoing diagnostic X-ray examination. By the end of August, 1964, over ten million dosimetric measurements will have been completed and the required evaluations made.

The purpose of this project has been to acquire the basic dosimetric information needed for the preparation of tables from which the radiation doses received by the population from diagnostic X-ray sources may be predicted. To be easily applied, these tables are being compiled in a form in which dosage values are expressed in terms of such parameters as the height, weight, age, race and sex of the individuals exposed in the population. For this reason, this laboratory has also conducted an anthropometric study of individuals of widely ranging characteristics to determine the raltionships between the anthropometric factors affecting dose and the parameters of height, weight, etc.

The dosimetric data are being collected by means of special apparatus designed in this laboratory. As produced, the data are recorded on magnetic tape and processed by an IBM 1401 computer. Data are then analyzed in a form which will ultimately enable the preparation of an extensive set of tables from which one may obtain the dose received by a broad range of critical tissues of individuals of widely varying anthropometric characteristics exposed with radiation produced under a broad range of X-ray conditions. This handbook will be published as a component of the Technical Reports Series, published by the Division of Radiological Health, U. S. Public Health Service

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RH 00091
RAD

"WHOLE-BODY COUNTING OF RADIOACTIVITY IN HUMANS"

At the Radiation Physics Department, University of Lund, Lund, Sweden, the following main research projects are presently being carried on:

1 Assessment of radioactivity in humans by whole-body counting technique.

2 The bioenvironmental contamination with radionuclides and the transport mechanisms involved.

3 The use of radionuclides for medical diagnosis.

4 Radiation dosimetry in radiology and radiological protection.

Project 1 and, to a certain extent, project 2 have been supported by the grants RH 00091-01, 02 and 03.

1 a Whole-body counting geometry

For several radionuclides and their chemical compounds redistribution within the body makes the 42 cm-chair geometry less suited for accurate whole-body activity determinations. Therefore we have developed a "scanning-bed geometry" with two scanning detectors, one above and one below a stretcher (1). The efficiency of this geometry using 5" x 4" NaI(Tl) crystals, depends very little on the distribution pattern of the activity in the body; for instance, regardless of the distribution in the body the whole-body activity of most radionuclides may be assessed with an accuracy better than 15%.

1 b Bremsstrahlung measurements of beta emitters in the human body

In a previous paper (6) we have reported on the use of thin NaI(Tl) crystals for assessing the total body activity of beta emitting nuclides such as ^{90}Sr by means of bremsstrahlung measurements. Further studies of this problem have shown that large, thick NaI(Tl) crystals in many respects are more advantageous, particularly when large amounts of interfering gamma emitters are present in the body.

2 Several subjects have been measured with an 8" x 4" crystal in the scanning bed geometry and it could be proved, that a 2 hour measurement, shared between subject and background, would reveal a contamination of about 50 nCi ^{90}Sr in a subject containing 40 nCi 137 Cs.

RH 00091 (continued)

2 a The enhanced radiocesium level of people in northern Sweden

Extensive field studies of the ^{137}Cs level of people on special diets, both Lapps and non-Lapps, in northern Sweden have been performed since 1961. Its relation to age, sex, occupation and food consumption as well as to the seasonal and geographical variations have been analysed. Levels 10 to 40 times greater than in southern Sweden are frequently found (3).

2 b The human metabolism of radionuclides

The retention and metabolism of different radionuclides have been studied, particularly for radiocesium. Several methods have been used, for instance intravenous injection of ^{137}Cs, oral administration of ^{137}Cs and ^{132}Cs, controlled change of dietary intake of ^{137}Cs, and body buildup analysis of ^{137}Cs from food intake. For adults we have obtained a biologic half-time in the range 60 to 90 days for 12-year old boys 45 days and for newborns about 20 to 25 days. We also found a new fast component of the cesium retention; 1 to 5% of the administered activity is excreted with a rate corresponding to a biologic half-time of 2 to 3 hours (4).

Special investigation of maternal and infantile metabolism of radiocesium has been performed, for instance the transfer of activity from mother to child via placenta and later via breast milk (5). At parturition the cesium concentration of the infant was close to that of its mother.

2 c The fallout accumulation in the biosphere

An extensive program is being carried on dealing with the uptake and deposition of various radionuclides from nuclear weapons tests in natural ground vegetation. Samples are collected from a number of plots from various parts of Sweden. Fresh water fish are also being studied.

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RH 00104
RAD

"BODY COMPENSATION IN DISEASE STATES"

The project to be accomplished under this grant was in two parts. The first of these two parts was the construction of a new and powerful beta-ray counter suitable for assaying K^{42} in large liquid samples with high efficiency. The second phase of the project was the use of this device in the performance of a series of measurements of total exchangeable potassium (K_e) in sick patients. This second portion of the project was also to be supported by the research program of the Boston Veterans Administration Hospital.

During the first year of the research grant, the beta-ray detector referred to in the first paragraph was constructed. The beta-ray counter is in the form of a vise. A liquid sample is placed between the two jaws of this vise in a novel sample holder. The geometry is exceedingly reproducible. The efficiency is 28% for K^{42} in aqueous sample of 80 ml. volume. As a result, $K_e$may be measured in man using a dose of only 10 uc of K^{42}, even when equilibrium samples are collected as long as 44 hours after tracer administration, at which time the body burden is 1 uc or less.

This new beta counter was used in conjuction with a specially constructed NaI:Tl well scintillation counter which would accommodate 25 ml. of sample within the crystal. These two detectors were employed in our method for separating the isotopes Na^{24}, K^{42}, and Br^{82}. The method employs both physical, chemical, and physiological differences between the three isotopes to effect separation which is very little different in accuracy from methods which use only one isotope at one time. A preliminary report of this method was presented in a symposium on body composition of the New York Academy of Sciences and published in Annals of New York Academy of Sciences, Volume 110, p. 246, 1963. A complete presentation of this method was published in the Journal of Applied Physiology, 1963, 18: 1252.

Part two of this research project was accomplished without utilizing the funds alloted for the second and third years of the research grant. A research fellow was not obtained, and the research was supported by Veterans Administration Research & Education funds. Measurements of total exchangeable sodium (Na_e), Ke, total exchangeable chloride (Cl_e) and total body water (TBW) were made in a large number of seriously ill patients and a few healthy men. The patients had illness

RH 00104 (continued)

associated with disorders of nutrition and water and electrolyte metabolism ranging from cachexia to extreme obesity and from dehydration to massive anasarca. The results show that in this highly varied group of subjects neither Na_e, K_e nor Cl_e was correlated at all well with TBW when considered singly. Cl_e in fact was not considered to add useful information in the absence of information regarding other anions. However, the sum of Na_e and K_e correlated exceedingly well with TBW ($r = .991$). Additional relationships containing serum cation concentrations had even higher degrees of correlation. Furthermore, it was found that expressions capable of predicting Na_e or K_e could be derived from the data.

The results of this study were completely consistent with the very significant regression reported by Edelman and his associates, J. Clin. Invest. 37: 1236, 1958. There was also complete agreement between the two groups of information regarding the new regressions which were discovered during the analysis of our data. The results of this study were published in J. Applied Physiology 18: 1963. A preliminary presentation of this information was made at a symposium on body composition New York Academy of Sciences and was published in the Annals of the New York Academy of Sciences 110: 978, 1963.

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RH 00105
ESE

"CALORIC MEASUREMENT OF X-GAMMA RADIATION"

1. Construction of the Calorimeter.
A calorimeter suitable for the measurement of beamed radiation was designed and constructed. This apparatus essentially consisted of a brass tank of approximately 1 cu. ft; inside the tank, and thermally insulated from it, were placed various materials in which it was desired to measure the absorbed energy. The tank was immersed in a temperature-controlled water bath, which was surrounded by insulation. A tunnel containing a series of thin windows allowed X-ray beams to reach the absorbers. Techniques were developed so that the use of a vacuum in the inner tank was not required; thus, the windows could be made thin enough to give a negligible attenuation to low voltage X-rays.

Temperature changes in the absorbers were detected by various types of thermistors embedded in the absorbing materials, and the results displayed on a wide-strip recorder. The calorimetric apparatus was capable of accurately measuring temperature changes as low as $10^{-4}\,^{\circ}C$ per minute, and was acceptable for making measurements on a variety of types of radiation.

2. Measurements on 2 Mev X-rays and Cobalt-60 Gamma Rays.

The initial use of the calorimetric apparatus was in the measurement of the energy in a 2-Mev X-ray beam from a Van de Graff X-ray generator. The beam was totally absorbed in a lead cylinder; the resulting temperature rise was compared with that produced by introducing a known amount of electrical energy enabling the beam energy to be measured with an accuracy of a few tenths of one percent. Using a calculated beam spectrum, the measured energy was converted to roentgens and compared with the results of ionization measurements made by placing a calibrated thick-walled Victoreen 25-r chamber inside the calorimeter tank, at a position corresponding to the front face of the absorber. The resulting comparisons showed the ionization chamber readings to be 1 to 5 percent low, with the variation depending mainly on the amount of chamber stem exposed to the beam. Similar absorption and ionization measurements were made on our Cobalt-60 teletherapy unit, with similar results.

3. Absorption Measurements on 100 Kv to 250 Kv X-rays.

The calorimeter was used to make energy absorption measurements on clinically-used X-ray beams in the low and medium Kv range. Plastics were used to simulate soft tissue, and aluminum for bone. Comparison with ionization measurements gave rads per roentgen conversion factors for these primary beams; measurements using aluminum absorbers embedded in tissue-equivalent wax gave average rads per roentgen factors in bone at a depth of 2.5 cm from beams within the same quality range. The results were presented in a paper in "Radiology".

4. The Calorimetric Determination of the Cobalt-60 Spectrum in Tissue.

The gamma rays from Cobalt-60 which reach a deep-seated tumor are degraded by scatter from the source, the collimators, and the tissue. We have placed various thin metal absorbers 10 cm. deep in tissue-equivalent wax, and have attempted to derive the spectrum from calorimetric measurements of the energy absorption. Initial attempts have not yielded sufficiently reproductible data, but we feel the method offers promise of eventual success.

5. Spectral Measurements on 100-250 Kv X-rays.

The comparison of measured energy absorption ratios with calculated ones requires an accurate knowledge of the spectra of the X-ray beams used. Thus we have made some preliminary spectral measurements on the direct X-ray beams, using a 2-inch NaI scintillation crystal. We are now undertaking a more elaborate program of X-ray spectral measurements, which will eventually cover the entire range of therapeutic X-rays.

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RH 00112
RAD

"RADIOACTIVE NUCLIDES IN TEETH AND BONE"

This study is in progress with portions of the results available. A report in Science (140:176-177, 1963) presented data obtained from noncarious deciduous incisor teeth from bottle-fed children born in St. Louis from 1949 through 1957. This data, subsequently expanded, show that 0.15 pc Sr-90/gm Calcium in 1947-born teeth increased to 2.56pc/gm Calcium in those born in 1957. Enamel contained 32% of the Sr-90 in the crown with the remainder in the dentin. The Sr-90 content between 1955 and 1957 increased but at a slower rate than for 1954 and 1955. The sharp rise in Sr-90 content of teeth between 1954 and 1955 coincides with a period of extensive nuclear testing begun in 1953. It appears that the Sr-90 content of teeth represents a measure of the total body burden at the time the teeth are formed, and our data suggest a gradual increase in total burden over the years of this study.

Similar studies have been made of carious first and second molar crowns and their roots during the birth years 1947 through 1958. For children born in 1947 who were bottle-fed, the crowns of both molars contained the same amount of Sr-90 (0.21 pc/gm Ca). The values increased regularly to 3.97 pc and 4.53 pc/gm Ca for first and second molar crowns respectively for children born during 1958, with no indication of reaching a plateau. During this period, the first and second molar crowns of breast-fed children are consistently lower in Sr-90 than those from bottle-fed children by about 35%.

The Sr-90 content of roots of first and second molars is consistently higher than comparable crowns during the birth years 1949 through 1955, but tend to approach the same values between 1955 and 1958. These root: crown values demonstrate differences in exchange and deposition rates of Sr-90 in the metabolically more active root tissues during a period in which Sr-90 fallout increased.

It is apparent from these data that the Sr-90 content of deciduous teeth continues to increase. The test ban treaty in 1963 suggests that monitoring of deciduous teeth of children born between 1958 and 1964 will be necessary to thoroughly evaluate the Sr-90 accumulation. Another study is under way to compare the Sr-90 content

RH 00112 (continued)

of tooth buds and alveolar mandibular bone in human fetuses formed from 1961 through 1964. These data will be available for comparison with tooth Sr-90 content of normal children born during these years.

A study considering Sr-90 balances of rabbits grown in the laboratory on rations containing known amounts of naturally occuring contamination has been completed. Complete balance studies indicate that utilization of dietary calcium over that of Sr-90 by the total rabbit body occurs by a factor of 3.8, a value similar to the factor of 4.0 found in man and other animals. In 35-day-old rabbits fed a commercial diet containing Sr-90 for 40 days, calcium utilization over that of Sr-90 was 3.7, 4.2, 4.5 and 5.2 for teeth, jaw, vertebral and leg bones respectively. The similarity between the values of calcium utilization over that of Sr-90 for the balance studies and tooth studies suggests that rapidly growing calcified tissues, such as rodent teeth are essentially in equilibrium with the diet, and rodent teeth may represent a useful index for the estimation of Sr-90 total body burden.

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RH 00137
RAD

"THERMOLUMINESCENT DOSIMETRY (PHANTOM AND HUMAN SYSTEMS)

The first year's work undertaken to develop a suitable in-vivo radiothermoluminescent (RTL) dosimeter has progressed satisfactorily.

The LiF dosimeter is less energy dependent than the $CaF_{2:Mn}$ but the latter dosimeter is more sensitive to low radiation dose values. The above characteristics are based upon the use of a four pi reader using a very low dark current prototype photomultiplier (RCA C-70101B). The tube is not cooled during operation. Dark current is less than 10-11 amperes at room temperature and one thousand volts DC. During a thirty second heat-read cycle, no integrated dark current has yet to be recorded. The use of this tube makes possible the detection of very low radiation exposures. Since RTL is a surface effect in this system, half the light and hence the signal is lost when dosimeters are viewed by one photomultiplier tube. To improve light (signal) collection efficiency, a four pi fluorimeter was designed and is being constructed which permits the dosimeter to be viewed on two sides simultaneously by two opposing PMT's.

RH 00137 (continued)

Three types of thermoluminescent phosphors are under investigation. These are LiF, CaF$_2$Mn, and CaSo$_4$Mn. They are in the form of permanently encapsulated dosimeters having the following characteristics:

Type of Heating	Size	Weight of Activant
a) Contact: conduction through glass envelope	1mm O.D.x8 mm	8 milligrams
b) Same as (a) but with E-C* coating	3mm O.D.x8 mm	8 milligrams
c) Straight-through platinum electrodes	2mm O.D.x10 mm	8 milligrams
d) Hairpin platinum electrodes	2mm O.D.x10 mm	8 milligrams

*Electrically-conducting coating.
These dosimeters are currently being studied with respect to a) reproducibility of dose readings. b) accuracy. c) energy dependence. d) linearity. e) metallic shielding for correction of energy dependence..

The second phase of the study pertains to the electronic readout and mode of heating the various types of dosimeters. At the present time, one reader system has been designed for the conduction heating. A second reader employing a 4pi geometry arrangement is being fabricated for the electrode heating type of dosimeters. Seven types of photomultiplier tubes have been investigated for their stability, signal to noise ratio, thermal stability and minimum detectable signal (for milliroentgen dose values).

At the present time, both the glow curve, peak, and integrated values are obtainable provided *a priori* information is known relating to the approximate dose delivered to these dosimeters. A phase of this study is to eventually possess an electronic system so that an "unknown" dose can be measured (integrated) and the peak value also obtained.

Another parameter to be considered is the study of single solid crystals of LiF (personal communication with Dr. J. Cameron). Parameters considered during the first year are summarized below:

Phosphors (3) LiF, CaF$_2$:Mn, CaSo$_4$:Mn
Photomultiplier Tubes (7)
Heating Mode (4) conduction heating, current through, E-C and R-F fields
Method of encapsulation (3) hairpin, straight-through, regular glass encapsulation
Fluorimeter geometry (2) 2 pi for conduction heating, 4 pi for electrode heating
Read-out mode (2) integration and peak amplitude
Shield(s) for correction of energy dependence (4) lead, cadmium, gold, platinum
Heating mode (2) 15 and 30 seconds.

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RH 00252
DEN

"STRONTIUM-90 IN DECIDUOUS TEETH IN THE GULF COAST AREA"

About 5000 deciduous teeth per year are being collected from each large metropolitan area along the Gulf Coast from Texas to Florida, and including Puerto Rico. These teeth are being assayed for Sr-90 as a means for monitoring the body burden of radioactive fallout from nuclear testing.

The program has three phases.

1. The Collection of the Teeth.

In general the collection is handled for us in the various metropolitan areas by local sections of the American Chemical Society, local chapters of the American Dental Society, local Dental Alumni of Loyola, or faculty of local Dental Schools. We ship packages of mailing containers and explanatory materials directly to the agency which will distribute them to first grade students, usually the local school board. The local committee arranges for this and for getting publicity in the local news media. The parents of the children mail the teeth directly to us, paying the postage themselves. The inside of the mailing container is a form which the parents fill out with information helpful to the statistical treatment of the data. We also provide publicity materials for use by the local committees. For instance, a New Orleans television station is preparing for us, gratis, a videotape describing the program, which will be duplicated and sent to all the local metropolitan areas.

2. Diagnosis and Cataloguing of the Teeth.

The individual teeth are diagnosed by a pedodontist with the assistance of four senior dental students. Each tooth is then assigned a number and affixed to a numbered spot on a 5 x 8 card, each of which holds 100 teeth, a space-saving and readily accessible method of storage. A coding form is filled out for each tooth for later transferral to an IBM card for processing in the University's IBM Computer Center. The basic philosophy behind such detailed and comprehensive storage of information is that, besides furnishing the necessary statistical information for the Sr-90 study, such a large volume of teeth should also furnish a large body of information of interest to basic dental research. To this end, besides the information sent in with the tooth, the IBM card for each tooth contains [illegible] items of dental diagnostic information, such as developmental deficiencies and so forth.

RH 00252 (continued)

3. The Sr-90 Assay.

After spending an unconscionably large amount of time on a laborious method with many chemical manipulations, we now assay the teeth by a modification we have developed of the ion-exchange method of Farrabee, which was originally intended for Sr-90 in urine, water, etc. The complete chemical preparation for counting, including a quantitative determination of Ca, can now be done in four hours. We now have eight columns set up for this process. The beta counting is done on a four-channel low-level beta counter with manual sample changers.

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RH 00260
RAD

"LEVEL OF DENTAL RADIATION HYGIENE IN COMMUNITY"

Various projects and studies were undertaken by the author in past years in the field of ionizing radiation as it relates to dental X-ray machines. This grant is intended to evaluate, in part, the effectiveness of past actions and to study and introduce new techniques of radiation hygiene where practical and possible.

Since every dentist in Greater Hartford (approximately 300) received from the official health agency appropriate filtration and beam collimating devices (as early as 1957-1958), a Surpak study, as part of this grant, was undertaken to determine the effectiveness of that program. The findings of this study will give some indication of expected compliance in other communities.

A second phase of this undertaking was to resupply those dentists whose X-ray machines were not properly filtered or collimated.

Since filtration, collimation, the use of "Ultra-Fast" film, an electronic timer, leaded lap apron, optimum darkroom facilities, film exposures commensurate with diagnostic needs, only using film holders, have all been stressed over and over again, it was decided that the next most appropriate action to reduce scatter and secondary radiation would be the adoption of an open-ended metal cone to replace the plastic pointer cone presently found on dental X-ray machines.

From past studies, the XRM and Weber dental X-ray units were found to be most offensive from the standpoint of penumbra and leakage radiation from around the primary port. It was decided to tackle these machines first, and accordingly an open-ended metal column was designed to provide a target-to-skin distance of seven inches. These have been produced at a local machine shop and are now available. My principle efforts for the remainder of the grant period is to demonstrate their use in the office of each dental practitioner and encourage his acceptance of this new device.

This is being done by making an appointment with the practitioner, visiting his office, exposing two 5" x 7" radiographic films -- one with plastic pointer cone, the other with the open-ended column, developing them in his office, showing him the difference -- a picture speaks a thousand words.

A personal visit is almost necessary; since the item is somewhat heavy there is need to counter-balance the head of the X-ray unit. This is quite difficult in some of the older units because of no specific counter-balancing screw. In addition, there is need to discuss increased exposure time due to the slightly longer cone and technique of film exposure. At each office visit, an ionization chamber if brought along to demonstrate radiation and methods of protecting the patient as well as office personnel.

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RH 00283
NTN

"ACCURACY OF ASSAY BY BODY COUNTERS OF K40 IN MAN"

The project has been designed to evaluate the following points:

1. What is the accuracy of the assay of potassium-40 content of man in whole-body counters.
2. Can a single anthropological measurement be made which will produce an acceptable variance for the geometrical factor used to calculate the potassium-40 and cesium-137 content of man.
3. Can whole-body counters be used to assess the nutritional status of individuals and of populations.
4. What is the minimum inherent uncertainty in the measurement of radioactivity in man.
5. How does the accuracy of measurement of potassium-40 in man by crystal scintillation whole-body counters compare to the accuracy of measurement by liquid scintillation whole-body counters.

The subjects being used in this study are clinically healthy subjects with their weights ranging from 45 kg. to 160 kg. The following measurements are being made:

1. Height, weight, limb and trunk lengths and diameters.
2. Skinfold thicknesses
3. Total body water
4. Total exchangeable potassium
5. Potassium-40 and cesium-137 assay in a crystal scintillation whole-body counter and a liquid scintillation whole-body counter.
6. In selected subjects a cesium-137 assay in a crystal scintillation whole-body counter.

From these data we will calculate lean body mass, mean body thickness, height/weight ratio, skeletal mass, efficiency factors for both types of whole-body counters, ratio of exchangeable potassium to body potassium calculated from the assay from K^{40} in both whole-body counters, lean body mass, content of potassium total body fat, and regression of skin fold thickness against total body fat. These data will be analyzed so that the anthropological factors responsible for the variance in the whole-body counter efficiency can be determined. A model will be formulated to attempt to provide a physical explanation for the variance in the efficiency factor.

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III. DEVELOPMENT OF METHODOLOGY FOR EXPOSURE REDUCTION AND CONTROL

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RH 00042
MET

"COMPOUNDS TO PROMOTE EXCRETION OF RADIOISOTOPES"

We are investigating compounds to promote the excretion of radioisotopes from animals. Our general plan involves determining retention patterns for specific radioisotopes, studying the effects of element deficiency and sufficiency on these retention patterns, and finally investigating the value of metal chelates in removing the corresponding radioisotopes. Our investigations are being carried out mainly with rats but some studies are being made with chickens.

To date we have determined retention patterns of the following radioisotopes: calcium-47, chromium-51, cobalt-58, iodine-131, iron-59, manganese-54, strontium-90, vanadium-48, and zinc-65. A standardized procedure has been developed using young and old rats of both sexes. Rats are injected by tail vein with ca. 5 μc of a specific radioisotope, and groups of four rats are sacrificed at intervals of one to twenty days. The animals are dissected and percent radioisotope retention for each tissue determined. Correlation coefficients of blood and tissue retentions have been calculated for most of the radioisotopes by computer analysis. Since zinc deficiency is produced so easily in poultry, studies of zinc deficiency and sufficiency on zinc-65 retention have been carried out largely with chickens. A number of aspects of vanadium-48 retention have similarly been investigated with the aid of chickens. Chromium-51, iodine-131, strontium-90, and zinc-65 are of especial interest because of their presence in the biosphere as a result of nuclear reactions.

Our work has brought out that certain radioisotopes are retained by hair and aorta. Other investigators have shown that radioiodine, radioselenium, radiostrontium and radiozinc accumulate in the hair, but no work has been done on the retention of radioisotopes by aorta. We can add radiomanganese and radiovanadium to this group of hair and aorta seekers. Since radiocalcium and radioiron do not accumulate in hair or aorta, although stable forms of both elements are present in significant quantities, interesting contrasts in metabolism are evident.

We are now beginning the study of metal chelates as a means of promoting the excretion of the corresponding radioisotopes. There are about 100 chemicals that come into consideration, and fortunately

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many have been examined in connection with the absorption of zinc in poultry nutrition. This will greatly reduce our work since some very definite differences are apparent, especially from the work of Kratzer at Davis, California. For this work, we are developing a whole-body counter for use in the animal work.

Our studies have been done partly in connection with the following programs: CA 03952, NB 00692, and HE 07219. Three publications have appeared or are in press, and an additional three have been submitted or are ready for submission.

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RH 00073
RAD

"RADIOACTIVITY IN MARINE ORGANISMS AND ENVIRONMENT"

Gross beta activities have been obtained from a variety of marine organisms from selected locations in the Thames and Niantic Rivers, (Connecticut) at regular intervals since April 1960.

Algae show higher levels of activity than all other organisms examined. Potassium-40 accounts for nearly all of the gross beta activity with the exception of two algae, Fucus and Ascophylum.

In these two organisms about 70% of the activity can be attributed to ruthenium isotopes. This has been verified by chemical separation and subsequent radio assay. In the upper Niantic River, values obtained from Fucus are in excess of those reported for those obtained elsewhere in Fishers Island Sound and its estuaries.

Fluctuations in gross beta levels occur from month to month. It would be anticipated that peak activities would occur in summer or during maximum activity of the organism, followed by a gradual decline to the lowest values at the time of minimum activity during winter months. Such a trend is difficult to demonstrate since so many organisms exhibit peaks or at least periods of high beta activity in winter.

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RH 00074
RAD

"RADIOACTIVE ACCUMULATION LIMITS IN EDIBLE SHELLFISH"

The amounts of radioactivity taken up by edible clams, oysters, shrimp, and other non-edible related shellfish, all from salt water, were investigated under laboratory conditions. In practice a concrete aquarium 18 x 7 x 4½ feet was cured with salt water for a year, then used to store wild stocks of the above animals. Maintenance in good physiological condition was achieved by controlling the salinity, and by the use of commercial fertilizer to provide plankton as food. Some oysters remained viable for a year, and shrimp grew to maturity in the tank. Ocean water was brought from the Atlantic and the Gulf in a monel steel tank, capacity 350 gallons.

Animals to be used were checked for natural radioactivity, then exposed to selected radioisotopes for given lengths of time. Exposures were made to radioisotopes dissolved in sea water, and combined in food microorganisms. In the latter case the radioisotope was ingested in food by the filter feeder. For this purpose stocks of such marine algae and protozoa as *Navicula*, *Nitzschia*, *Chlamydomonas*, *Dunaliella*, and many others were grown in unialgal culture.

Oysters (*Crassostrea virginica*) were exposed to Zn^{65} and Cs^{137} in dosed raw sea water, dosed filtered sea water, and in sea water containing suitable food concentrations of the green flagellate *Platymonas*. Zn^{65} was rapidly removed from solution, and from *Platymonas*. Equilibrium probably varies according to the concentration of Zn^{65} in the environment. A very high concentration factor was found for oyster tissues, as high as 25000:1, but was low in the shell.

Cs^{137} was also taken up from the water and from *Platymonas*; tissue concentration ratio was highest 64 to 1, very little being found in shell. Cs^{137} was not taken up by the glass of the aquaria, whereas 40% of the Zn^{65} was adsorbed. However concentration of Cs^{137} by oysters was so low, 0.04 μc/gm. dry weight, in the experimental work, that it could hardly be a hazard.

Edible clams (*Venus mercenaria*), showed an aversion to ruthenium. Cerium (colloidal) was removed from the environment, and concentrated both on old shell and in soft tissues. Cobalt (ionic) had concentration factors of 1250, 18 and 2 for cobalt alone, and 1200, 13 and 3 for clams fed dosed *Platymonas* for old shell, soft tissues and shell

RH 00074 (continued)

respectively. Clams behaved toward promethium as toward cerium. These four radioisotopes were retained for two weeks by soft tissues at 63% when their source was *Platymonas*, even in fresh nondosed sea water.

It is suggested that old clam shells, because they collect radioactive isotopes to such an extent, might have an extensive use in detecting levels of radioactivity in inshore waters.

Zinc^{65} was also studied as to its concentration, principally in *Penaeus*, *Crassostrea*, *Mytilus*, *Chion*, and *Venus*. In *Penaeus*, rate of metabolic uptake is dependent on medium zinc concentration, with maxima above 10^{-4} moles per liter. There is little nonmetabolic uptake. The abdominal muscles (human food) took up insignificant amounts.

In *Venus*, very low concentration ratios of Zn^{65} were obtained for both tissue and fluid, and even less for the muscle. This animal took up the least Zn^{65} of all those reported on. *Chione* and *Mytilus* were not so extensively studied with respect to the tissue accepting the greatest amount of Zn^{65}, but neither is a human food organism.

Many environmental factors, such as the amount of stable isotope present, the effects of other ions upon the uptake of a single ion, uptake at temperatures ranging from 10°C to 30°C, pH, and length of exposure, were investigated, but cannot be included in this summary summary.

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RH 00075
EAD

"RADIOBIOLOGICAL RESEARCH ON MARINE ORGANISMS"

The radiobiological program at the Marine Biological Laboratory is essentially a summer program extending from the middle of May until the middle of September. Radiobiological research is carried on at a reduced scale during the other months of the year.

The Marine Biological Laboratory provides research space for investigators on application, each working on a problem of his own choosing. In addition there are available a variety of research services including space and services for radiological research. Each investigator has his own research laboratory but in addition, ten laboratories are set aside as radiobiological service laboratories under the supervision of the radiation safety officer. There is a storage and preparation room with adjoining space for radioactive waste, a "high level" hot laboratory, a "low level" hot laboratory, an instrument room, a Carbon-14 and Tritium laboratory, a small electronics shop, and three counting rooms.

RH 00076 (continued)

One laboratory houses a special cesium-137 irradiator with two sources, one above and one below the material to be irradiated. By varying the distance of the sources from the material, a dose rate range of 100 to 5000 r per minute is provided.

The Laboratory (M.B.L.) holds an AEC license for the procurement and use of radioactive isotopes. Investigators intending to use radioactive materials state their requirements in their applications for laboratory space. Regular supplies or stocks of certain isotopes are maintained on hand at the Laboratory for general use including P-32, Fe-59, Cu-65, I-131, K-42, Na-24, Zn-65, Hg-203, Ca-134, Rb-83, H-3 thymidine, H-3 cytidine.

A very broad spectrum of biology is represented at the Laboratory. Since the area of research is determined by the individual investigators the projects range from biophysics to ecology. The marine biota furnish materials frequently with unique anatomical, physiological or chemical characteristics peculiarly well adapted for radiobiological investigations.

The gametes of a number of marine forms are peculiarly well suited to the study of the effects of radiations on problems of fertility and cell multiplication. This includes the irradiation of the isolated sperm or eggs or the fertilized ova. The regularity of cell division under normal conditions is remarkable in some forms with deviations from the normal furnishing information on induced abnormalities. Radioisotopes are particularly valuable in investigation of the biochemical features of embryonic differentiation, particularly in protein synthesis.

The problem of transport across membranes can be studied on a variety of materials including the giant axon of the squid where tracer techniques using radioactive sodium and potassium have furnished significant information on the origin and propagation of electrical potentials in nerve.

The unusual anatomical segregation of the islet tissue of pancreas from the exocrine tissue of the pancreas in some of the fishes provides an unusual opportunity to study the glucose metabolism of the islet tissue utilizing glucose - C^{14} as well as induced diabetes in the intact animal resulting from extirpation of the islet tissue.

Photosynthetic processes in benthic diatoms can be studied to advantage as a general phenomenon by following uptake of C-14 labeled sodium carbonate when the diatoms are incubated under varying conditions of illumination.

The above serve as examples of the fifty or so programs carried on each summer at the Marine Biological Laboratory in which radioactivity is involved. Obviously the wealth of diverse marine forms furnish uncounted opportunities for research in the area.

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RH 00077
ESE

"EFFECTS OF RADIUM ON STREAM BIOTA BELOW URANIUM MILLS"

This project was designed to explore the effects of radium-226 on stream biota below uranium processing mills. In approaching the problem, three areas have been of interest:

1) the radium-226 content of various samples from the rivers.
2) the accumulation of radium-226 by representative organisms under controlled experimental conditions, and
3) the distribution of one species of fish with respect to pollution in the Dolores River, Colorado.

Field collections were made on the Animas, San Miguel and Dolores Rivers of southwestern Colorado, beginning in January, 1960, and continuing until late fall of 1963. Collecting stations were selected to provide a control or nonpolluted station above each uranium processing mill, and a series of stations at various distances below the mills. Initially, nine stations were selected on the three rivers, but activation of additional mills necessitated the addition of three more stations. Grab samples of water and mud were taken at approximately monthly intervals, and samples of stream invertebrates and benthic algae were taken when present. Differences in water level and the transitory nature of some of the fish populations dictated the time of year for fish collecting. Extensive collections were made during August of each year.

Radium analyses were first made on water and mud from the field sampling to provide basic information on prevailing river conditions. Algae, insects, and fish are now being analyzed, as are additional water and sediment samples.

Field sample analyses give actual radium content, but tell nothing of exposure levels or length of time necessary for an organism to accumulate a particular amount of radium. Laboratory studies were undertaken with algae and fish to learn more about their uptake of radium. Goldfish (Carassius auratus Linnaeus) were used in experiments to determine the effects of temperature and radium concentration on the rate of radium uptake. These fish were chosen because of their hardiness, ease of procurement, and general value as a laboratory animal. Two genera of algae (Vaucheria sp. and Cladophora sp.) were similarly tested for radium uptake rate. Both of these algae occur in the rivers being studied.

RH 00077 (continued)

Among the effects of pollution on the Dolores River is a drastic decrease in the number of channel catfish (*Ictalurus punctatus* Rafinesque) in the fifteen or twenty miles below the mill at Uravan, Colorado. Data have been collected on upstream movements of these fish, and daily measurements of water temperature and pH made. Since the mill wastes are predominantly acidic, field measurement of pH is considered to be a dependable indicator of total pollution, and should allow clarification of the relationship of stream pollution to distribution of the fish.

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RH 00078
RAD

"ION EXCHANGE FOR HIGH-ORDER DECONTAMINATION"

The quantities of radioactive wastes that may be discharged into surface and ground waters are limited by the potential hazard to health that may result. Small installations, especially isolated research laboratories, are often faced with the need for costly and complex treatment installations that tax their capabilities to meet the requirements of initial cost and operating expense. When such installations are required to provide decontamination factors of 10^4 to 10^5, it has been customary to rely on evaporation as the treatment system. Unfortunately such systems are costly to build and troublesome to operate and more economic and manageable systems are clearly needed to achieve similar high orders of decontamination. It was for this reason that ion exchange was investigated as a process having the potential of an equivalent decontamination capability to evaporation, but more satisfactory operating characteristics.

Studies of high order decontamination by ion exchange were conducted in three phases; 1) laboratory studies of nonregenerative column operations for Sr^{90} and Y^{90} removal, 2) full scale plant studies of the treatment of a Sr^{90} contaminated organic waste, and 3) laboratory studies of regenerative column performance in treating Sr^{90} wastes. The laboratory studies of nonregenerative columns led to the design and guided operation of a full-scale plant handling the wastes from 300 Beagle dogs and situated at the Davis campus of the University of California. This plant consists of a primary settling and partial oxidation facility to prepare the organic animal wastes for further chemical treatment. Coagulation with iron salts at pH 4 to 4.5, sedimentation, and chlorination serve as preliminary steps to ion exchange treatment. The ion exchange plant involves a five-segment, counter-current column system. Each column segment, after saturation, becomes a package of solid waste and is ultimately disposed to the sea in concrete. Because of the high cost of resin, especially at larger installations, the study was continued in 1963 to examine the feasibility of regenerating the exchange columns to produce a concentrated liquid waste, thus allowing the prolonged reuse of the exchange media.

The investigation demonstrated that ion exchange is a practical means of handling strontium-90 bearing wastes at small installations and that it is also suitable for removing the cesium-137 isotope. These radioisotopes can be removed with decontamination factors of 10^4 to 10^5, providing certain conditions are met in the preparation of the wastes for ion-exchange treatment. Related studies with yttrium-91 and barium-lanthanum-140 indicate that ion exchange will be much less satisfactory for tri- and quadri-valent radionuclides. The more significant conclusions are summarized below.

1. The leakage of radionuclides through ion-exchange columns of considerable length serves to limit their decontamination performance. Such leakage results from the formation on-ionic radio-aggregates that have relatively small sorptive affinities for the solid phase. Aggregate formation was especially pronounced for yttrium and also appeared to occur in the case of strontium.

2. Non-exchangeable or aggregate forms of yttrium tend to dissociate to cationic species, but the rate of dissociation following removal of the cationic species is slow and may not occur within the normal interval of residence in an exchange column.

3. Trivalent and quadrivalent cationic radionuclides are capable of forming aggregates by hydrolysis reactions which may be followed by olation or oxolation processes to produce polymeric complexes. These complexes are the non-exchangeable aggregates responsible for leakage.

4. Aggregate formation may be minimized by maintaining solutions at low pH, generally less than 4, and reducing the concentration of suspended material, the latter being especially responsible for strontium leakage.

5. By adequate pretreatment, and with columns of several feet in length, it is possible to obtain strontium-90 decontamination factors exceeding 10^4 in the treatment of organically contaminated wastes. In the absence of organic contaminants the decontamination performance may exceed 10^5 and thus be comparable to evaporation. The cost of such treatment is closely equal to that of evaporation.

6. Optimum column performance is achieved by counter-current operation and by employing small-grain resins and minimal flow rates. Where ultimate disposal of the solid residue is to be ocean burial in concrete containers, the small volume of resin may be easily and safely incorporated into the final disposal package.

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RH 00096
RAD

"REDUCING PATIENT DOSE IN X-RAY DIAGNOSIS"

When this project was contemplated some six years ago, it was popular to spend much money and effort collecting data to show how distressingly large dosage might be in some diagnostic applications of X-ray. This project aimed, instead, at developing apparatus, techniques, and states of mind calculated to keep dosage at a minimum without reduction the clinical usefulness of X-ray examinations. This goal has been attained by several means which, grouped in order of dose-sparing, are:

1) improvement of rectangular collimators to confine the beam strictly to the area of the film being used.

    a) special devices to maintain this restriction during stereoscopic filming.

2) improvement of television-type image amplifiers and adaptation of them to gastrointestinal and cardiovascular examinations.

3) emphasis of the importance of developing film completely and exposing it automatically.

4) recognition of the fact that the aim of X-ray examinations is a diagnosis and the avoiding of slow film, slow screens, and nonscreen techniques merely for cosmetic purposes.

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RH 00113
RAD

"A STUDY OF DESIGN CHANGES IN DENTAL X-RAY MACHINES"

The average focal-skin distance realized with existing dental X-ray machines is seven inches. These machines are constructed with the focal spot of the tube located a short distance behind the base of the directing cone and in front of the high-voltage transformer. The added filter and the lead diaphragm are located at the base of the pointed plastic directing cone and radiation from the filter scatters through a large solid angle, thus increasing the exposure of the patient's gonadal and other regions as well as the exposure of the operator and film. The pointed plastic cone is also another source of scattered radiation. To produce sharper images which exhibit less enlargement requires the source-object distance to be increased. At present this is done by replacing the short pointed cone with a long open-ended cone which proves cumbersome in some applications.

Moving the X-ray tube to the rear of the X-ray head will provide the desired increase in the source-object distance without increasing the external length of cone. This maneuver will require that the design of the transformer be changed to permit the usable portion of the beam to pass through an opening in the transformer.

An X-ray tube with a radiopaque hood will reduce extra-focal radiation. A small aperture in the hood will allow the usable beam to emerge. This aperture will be covered with the necessary added filter. Scatter from this filter will be largely superimposed on the usable beam and the images produced by the two sources will coincide and reinforce each other.

When processed, each area of a radiographic film darkens in response to the exposure it has received from focal radiation, extra-focal radiation, leakage radiation, or secondary radiation which scatters from the diaphragm, filter or cone of the dental X-ray machine or from the irradiated tissues of the patient. Usually, radiation from many of these sources simultaneously exposes each minute area of film. To determine which sources of radiation have contributed to the exposure of a chosen small area on a radiograph, one has only to return the radiograph to its original exposure site in an experimental set-up with a phantom head, and then replace the chosen area with the minute aperture of a lead-walled pinhole camera.

When the exposure is repeated, those rays which formerly exposed the chosen small area on the film will now pass through the pinhole opening of the camera, continue in a straight line and eventually expose an X-ray film within the camera. In this manner, the irradiating sources are recorded and identified. Means are available for either eliminating or reducing each undesirable source of radiation in turn and thus the effect that each source exerts on the density and contrast of the finished radiograph can be studied densitometrically. The modified transformer and X-ray tube will be the means for altering the sources of undesirable radiation.

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RH 00117
ESE

"STUDIES ON BIOACCUMULATION OF FALLOUT IN GEORGIA GRANITE ROCK-OUTCROP ECOSYSTEMS"

Biogeochemical cycles of certain localized fallout particles are being investigated on granitic flatrocks in the Georgia Piedmont to ascertain body burdens among the biotic components. The rock outcrops are essentially lichen-covered (*Parmelia conspersa*) igneous materials. The undulating uplands are pocketed with shallow soil pits which support communities that range from single-species annuals to mixed-forb perennials. Excess surface water flows over the lichens and from one community to another; each community filters or removes some fallout radionuclides from the inflowing water.

The lichen *Parmelia conspersa* contained more gamma radiation than any other species. Body burdens for ZrNb-95, Cs-137 and Sr-90 during summer 1963 attained 150, 260 and 14.2 uuc/g dry wt. respectively. The cumulative body burden is related in part to the perennial habit of the lichen as well as its rapid rate for absorbing fallout-laden rainwater.

Viguiera porteri, a widespread, autumnal, annual, "aster" growing on shallow soil, carried more Sr-90 than any species. Body burdens in the 1962 crop approximated 125 uuc/g dry wt.; that for Cs-137 was 18 uuc/g dry wt. Other "strontifiles" include the moss *Polytricum communis* and the perennial succulent *Talinum teretifolium* with 13.5 and 55.5 uuc/g dry wt. respectively during spring 1962.

Broomsedge grass (*Andropogon virginicus*), cedars (*Juniperus virginiana*), pines (*Pinus taeda* and *echinata*) and the endemic oak (*Quercus georgiana*) in this order held relatively less gamma-emitters in 1962, although the range of variability among species for Cs-137 in particular was not large; that is, 9-10 down to 5-8 uuc/g dry wt. Sr-90 during summer 1962 on these plants ranged from 3.5 to 13.5 uuc/g dry wt.; no species-isotope pattern was established relative to Sr-90.

Generally, upland populations of a given species contained less radionuclides than lowland populations of the same species; the exceptions are explained by following pathways of water flow. Upland

RH 00117 (continued)

lichens had 2-3 times larger body burdens because excess water flowing over lowland lichens leached radionuclides. Upland cedar and pine had 1.5-2 times larger body burdens because they probably removed radionuclides from runoff water before that water got to the lowland populations. Otherwise, lowland populations apparently received the bulk of excess radionuclides and contained up to 3 times higher body burdens.

Among the insects, moths with complete metamorphasis contained less Zr-Nb-95 than those insects with incomplete metamorphasis. Honey bees contained less gamma-emitters than other insects. The endemic "rock-loving" grasshopper, Trimerotropis saxatilis carried 16.6 uuc/g Cs-137 in 1962 and the lubber grasshopper, Romalea microptera, carried 55 uuc/g ZrNb in 1963.

The skins of vertebrates, in this case field mice and fence lizards, contained more Zr-Nb-95 than the muscular bodies. With both species less than 10 uuc per animal of either Cs-137 or Zr-Nb-95 incurred.

Plankton filtered from water in a closed pond in July 1963 assayed about 400 uuc ZrNb-95 per gram, whereas the water assayed 14.5 uuc/l.

Food-chain transfer ratios are difficult to estimate accurately because of uncertain plant-animal relationships; nevertheless, numerous gamma-ray spectra indicate that animals as consumers carry less than 10%, on the basis of dry weights, of any radioisotope associated with the surrounding herbaceous plant species.

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RH 00124
RAD

"FISSION PRODUCT-SOIL ORGANIC MATTER COMPLEXES"

Most of the fission products from atomic detonations which are ingested by man via the food chain pass through a phase in the soil. Plant uptake of fission products is regulated by the reactions which take place between the soil and the fission products. Soil organic matter accounts for much of the cation exchange capacity in many soils and is capable of complexing metals in chelation-type reactions. The organic complexes which may form are often water-soluble and can be leached into the soil profile. Other complexes are insoluble and are precipitated on the surfaces of inorganic colloids.

RH 00124 (continued)

Due to the fact that soil organic matter is located near the soil surface where fission products are deposited and because it can form strong complexes soil organic matter may play a major role in determining the fate of fission products in soil and their availability to plants. Work under this project is directed towards two general areas--characterization and identification of fission product-soil organic matter complexes, and determination of the effects of soil organic matter on plant uptake of fission products.

Incubation studies have been carried out with Sr^{90}-Y^{90} contaminated soil. This was done to allow time for uptake by soil organisms and incorporation of the Sr into organic compounds. However, the results indicated that complexing of Sr^{90} and Y^{90} with soil organic matter takes place immediately and does not require long periods of incubation. One component was found to complex Y^{90} only in nonincubated soil extracts. Incubation of the soil or methylation of the soil extract with diazomethane prevents this complex from forming. The organic matter component has been tentatively identified as an aromatic amine.

Large amounts (about 75%) of the Sr^{90}- Y^{90} removed by hot water extraction was found to be associated with polysaccharide material. A method has been developed for separation of Sr^{90} and Y^{90} polysaccharide complexes so that a more detailed characterization can be made. Both positively and negatively charged components were found in the polysaccharide fractions which formed complexes with Sr^{90} and Y^{90}.

Soil contaminated with Ru^{106} was incubated and later successively extracted with various organic matter solvents. Approximately 1/2 of the Ru initially added to the soil was removed with the soil organic matter. Large amounts of the extracted Ru were associated with HCl and Na_2CO_3 extractions. Almost all of the Ru in the Na_2CO_3 and about 1/2 of that in the HCl are complexed with high molecular weight polymers. Chromatographic and infrared techniques are being used to characterize these complexes.

The effects of soil organic matter on plant uptake of fission products is being studied by excised root absorption from membrane equilibrium systems. Plant absorption of Sr^{90}, Cs^{137} and I^{131} is measured after an organic matter suspension is equilibrated with a salt solution. The difference in uptake between the suspension and solution phases indicates the effect of the soil organic matter. The organic matter has had a marked effect on the uptake of Sr^{90} and I^{131} but only a slight effect on Cs^{137} uptake. Studies are underway concerning the factors which influence the reactivity of the organic colloids in these systems.

Other experiments are being conducted to determine the influence of soil organic matter extracts in long-term absorption studies with cereal and vegetable crops grown to maturity.

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RH 00173
TOX

"EFFECT OF FOOD PROCESSING ON RADIOACTIVE FALLOUT"

The primary objective of this research is to determine the effectiveness of various unit operations involved in processing the commodity in removing Strontium 90 from a root crop, a fruit crop and a leafy crop.

Potatoes were selected as an example of a root crop. The unit operation investigated was peeling. Since the primary concern is with surface contamination, a secondary objective is to determine the amount of penetration and translocation, if any, of radiostrontium in the potato.

Two varieties of potatoes were selected. These were Katahdin and Sebago. The tubers of each variety were separated into three lots. The tubers of one lot were soaked in a solution of Strontium 90 for periods of 30 seconds, 3 minutes, and 30 minutes. These tubers were allowed to dry and autoradiograms were made at 0, 1, 5, and 6 days after treatment. Since the greatest depth of penetration occurred at the 30-minute exposure, the second lot was treated in a solution of Strontium 90 for 30 minutes, allowed to dry and subjected to five peeling methods at 0, 2, and 4 days after treatment. These included: hand peeling, abrasive peeling, abrasive peeling with a wetting agent added, lye peeling, and lye peeling with a wetting agent added. The third lot was untreated but subjected to the same peeling techniques as the treated potatoes. After peeling, the potatoes were sliced and dehydrated. The slices were ground, treated with hydrochloric acid, and placed on planchets for assay. Radioactivity was determined by gas-flow beta counting. Records were also made of weight loss due to peeling and condition of the tubers.

The results indicated that as exposure time increased, the depth of absorption of radiostrontium increased. A tenfold increase in exposure time (3 minutes to 30 minutes) nearly doubled the depth of penetration of Strontium 90. However, at 30 seconds exposure, there was no apparent absorption. As holding period from exposure to peeling increased, there was a slight increase in depth of penetration of Strontium 90.

The following conclusions were made concerning the effectiveness of various peeling methods on the removal of Strontium 90 from potatoes as determined under the conditions of this study. The amount of the

RH 00173 (continued)

radioisotope removed from the potatoes by any peeling method varied directly with the depth of penetration of Strontium 90 absorbed and amount of peel removed. The hand, lye, and lye with wetting agent peeling methods were very effective in the removal of radioactive material from treated potatoes. The amount of Strontium 90 removed was 95% or higher in all cases. However, the abrasive and abrasive with wetting agent peeling methods were not consistently effective in the removal of Strontium 90. The range in amount of Strontium 90 removed was 80 to 99 percent. In event of contamination of potatoes with radiostrontium, lye, or lye with wetting agent peeling would be the safest method to use from the standpoint of radiation exposure to the workers. Variety and physiological condition of the potato tuber, affected the amount of absorption of Strontium 90. These two factors were of prime importance and should be investigated further.

Based on the research conducted thus far, we would recommend that potatoes in the marketing channel, which have been subjected to Strontium 90 fallout, should be peeled as soon as possible using one of the lye peeling methods. This would effectively remove the contamination.

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"COLLOID-SOLUTE SORBTION OF RADIONUCLIDES IN WATER"

Little is known about the populations of the various organic and inorganic particles in natural water, but knowledge of the distribution of contaminants, especially radionuclides, among these microscopic and submicroscopic particles is essential for a proper understanding of their effect on the human use of the water.

In this project the organic and inorganic particles usually found in natural water are being isolated and separated in bulk amounts so that their role in the accumulation and distribution of contaminants in the water may be studied. The initial whole water samples are taken by quantitative methods so that, knowing the pre-history and mass of the sampled water, the results may be quantitatively applied to the general condition of the total water mass. The particle separations are made by continuous-flow and density-gradient centrifugation to separate the particles into (1) noncolloidal organic, (2) noncolloidal inorganic, (3) colloidal organ (virus), (4) colloidal inorganic, and (5) dissolved particles. At present, the amount and type of material present in each isolated group is characterized by such parameters as ultraviolet adsorption, electron microscopy, sedimentation rate, metabolic activity, and weight. Most of the effort at present is being applied to determining what materials are present in natural water and how they may best be isolated and characterized. As a final step, the amount and type of the various radionuclides present in the samples are determined for each fraction.

RH 00183 (continued)

At present a picture of the distribution of radionuclides among the micro-and submicroscopic particles of natural water is emerging and should be of value in assessing any potential hazard which may exist from the presence of radionuclides in natural water. The methods being developed are applicable to other problems of aquatic contamination.

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RH 00215
TOX

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"ACCUMULATION AND RETENTION OF RADIONUCLIDES BY TUBIFEX"

Preliminary studies on the environmental physiology of tubificid worms have been completed and studies on the accumulation and retention of radionuclides by these organisms have been started. Studies on the accumulation of radionuclides in specific tissues of tubificid worms and on the functional role of these organisms in the ecosystem are planned.

In order to evaluate the rate of uptake of radionuclides, it was necessary to have an understanding of the physiology of these worms. For this reason, the metabolism of tubificid worms under varying environmental influences was studied using the rate of oxygen consumption as the standard of measurement. Lowering of the environmental temperature of these organisms to near 0°C. produced significantly lowered oxygen consumptions. Additions of 1 ppm (nonlethal) solutions of copper sulfate or sodium pentachlorophenate produced significantly higher oxygen consumption values; however, zinc sulfate produced no apparent increase.

Environmental studies on the toxic effects of some inorganic and organic compounds to tubificid worms were tested by a standard bioassay procedure. Mean lethal dose values were established for lead, zinc, and sodium pentachlorophenate under various environmental conditions and the synergistic action of these compounds was determined. The toxic effects of six organic insecticides representing a wide spectrum of types were also studied and mean lethal doses were established for these compounds. In most cases, tubificid worms were found to be more tolerant to the toxic compounds tested than other aquatic fauna for which values are available.

The isotopes of primary interest in the bioaccumulation and retention studies are P^{32}, Sr^{90} and Cs^{137}. Labelled phosphate has been shown to be important in aquatic ecosystems and Sr^{90} and Cs^{137} are important because of their long half lives and their chemical and physiological resemblance to calcium and potassium respectively. A beta-anthracene well crystal attached to a photomultiplier tube, preamplifier, and decade scaler system is being utilized to measure the radioactivity in the samples because of its high counting efficiency for hard beta emitters and because the problems of geometry are minimized with the well type of detector.

A preliminary investigation concerning the uptake of radioactive phosphorous by tubificid worms has been completed. P^{32} labelled phosphate was used in the studies and tubificid worms were found to concentrate the labelled phosphate about two times the concentration of the solution. Studies are now in progress to determine the retention of radioactive phosphorous by tufificid worms from an inorganic Knop's solution and to determine the accumulation and retention of radioactive phosphorous from solutions with different combinations of sand, silt and clay substrate. Similar studies are planned for Sr^{90} and Cs^{137} in the near future.

Projected studies concerning the uptake of P^{32}, Sr^{90} and Cs^{137} in specific tissues of tubificid worms are planned for later in the year. Since very little is known about the physiology and metabolism of tubificid worms, these studies should help eludicate specific sites of accumulation and storage of the isotopes which are under study. Further studies will be carried out to determine the functional role of tubificid worms in the ecosystem. Tubificid worms labelled with P^{32}, Sr^{90} and Cs^{137} will be introduced into an aquarium ecosystem and the other organisms in this artificial ecosystem will be assayed for activity at various time intervals, to determine any transfer occurring.

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RH 00257
NTN

"CHARACTERIZATION OF RADIOPROTECTIVE FACTOR IN ALFALFA"

The presence in cabbage of a substance that reduces the radiosensitivity of guinea pigs fed a basal diet of oats and wheat bran has been confirmed. The present investigators have concluded that the beneficial factor (s) is also supplied by broccoli and alfalfa; and that there is no apparent requirement for the factor in the presence of a semi-synthetic diet. However, the effect of the plant substance cannot be duplicated by known essential nutrients, although combined supplements of B vitamins and crude steamed bone meal are beneficial. The effective agent in alfalfa is water-soluble, hexane-insoluble, and destroyed by ashing. Thermal sensitivity is indicated by the relatively low effectiveness of alfalfa that has been steamed and pelleted.

Two hypotheses can be offered to account for the responses observed. First, the bran-oats diet may impose a requirement that does not exist in conjunction with the purified diet, perhaps due to the presence of some substance detrimental to absorption or to nutrient imbalance. Alternatively, an unrecognized essential substance may be provided by both green plant materials and some ingredient of the purified diet.

Research in progress is directed toward isolation and characterization of the radioprotective factor(s) and elucidation of its mode of action. Potential green plant sources of the factor are now being screened, prior to selection of the most potent material for chemical isolation. Simultaneously, various parameters of response are being examined for suggested mechanisms of protection. These parameters, as well as various microbial systems, are also being studied with a view to developing a bioassay that will require less time and material than does the present guinea pig assay.

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IV. OTHERS

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RH 00050
RAD

"SECOND INTERNATIONAL CONGRESS OF RADIATION RESEARCH"

The National Academy of Sciences was pleased to receive a grant from the U. S. Public Health Service, Division of Radiological Health, of $26,090 to assist in meeting the expenses of United States participants in the Second International Congress of Radiation Research, held in Harrogate, England, August 5-11, 1962. This grant, together with other funds provided by the National Science Foundation, the Atomic Energy Commission, and the National Aeronautics and Space Administration, made possible the attendance of a distinguished group of American scientists, who presented a comprehensive report on the advances being made in this country.

Acting in behalf of and in cooperation with the Radiation Research Society, the NAS-NRC appointed a screening committee who reviewed and screened almost three hundred applications from which approximately one hundred and twenty were approved for partial support. The staff administrative services were furnished without charge, and essentially all of the funds available were utilized for the benefit of the U. S. scientific participants.

Two reports of the Congress have been issued: *Abstracts of Papers*, issued by the local organizing committee with support from the International Atomic Energy Agency, and a volume of proceedings, *Radiation Effect in Physics, Chemistry and Biology*, North Holland, Amsterdam, 1963; which contains the Rapporteurs' reviews of the more than three hundred papers presented. Copies of these reports have been furnished to the sponsoring agencies.

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RH 00229
RAD

"RADIOACTIVITY IN MAN: SECOND SYMPOSIUM"

ABSTRACT

Forty seven papers were presented to an audience of over 400. Highlights are reviewed below:

A feedback system that promises gain stability was reported by Dudley, Monahan, Raboy and Trail, describing an anticoincidence annulus that surrounds the sodium-iodide crystal and suppresses the Compton distribution. Laurer and Eisenbud explored the technical problems of low-level I-131 measurements in humans. Estimating the volume of local pools of blood was reported by Sevelius. A sensitive counter for determining Pu-239 in vivo was developed by Taylor and Rundo.

Of greatest interest in the application of whole-body counters is the study of potassium. Contributions covered calibration of both 4-pi liquid and single-crystal instruments, correlation of total-body potassium tissue-potassium measurements and investigations of the dependency of total body potassium content on age, sex, and race. W. H. Blahd described observations on the interrelations of body potassium and body water in patients with primary muscle disease. The subdivision of total body weight into lean and fat fractions by the method of Forbes, Gallup and Hursh can be made with uncertainties of a few percent.

Cobalt metabolism can be studied elegantly with whole-body counter techniques. Clinical tests such as studies of vitamin B-12 absorption in the diagnosis of pernicious anemia can be done with great ease. Perhaps the most fascinating applications depend on the long physical and biological half-life of this isotope, whereby amazingly long-term turnover studies can be performed precisely and simply with very small tracer doses. In the area of iron absorption, turnover and excretion, it is abundantly clear that clinical investigation is greatly facilitated by whole-body counter methods. Useful tests include iron uptake, studies of daily requirements for iron and the rate of iron incorporation into hemoglobin. Other research and clinical applications included further investigation of radium burdens, studies of sodium space and total exchangeable sodium with Na-22, extracellular fluid volume with Br-82 and metabolic studies with such gamma emitters as Cr-48, Sr-85, and Au-198.

Jagger, Hine, Cardarelli and Burrows watched the effect of dietary sodium on sodium turnover in man. Rama, Sastry, Weiland and Bass followed the zirconium-95/niobium-95 fission pair by external counting and tissue analyses. The transient equilibrium between Zr-95 and Nb-95 is disturbed by the tissues during distribution. Bone preferentially concentrates zirconium, and the soft tissues prefer niobium. There exists a three-cornered relationship between composition and history of the fission mixture at the time it enters the body, the quantities of components that can be measured by external counting and the biological behavior of the components. The interrelation of these three factors must be learned if external measurements are to assess the radiation hazard of a particular fission product burden.

Worthley studied Cs-137 body burdens from a southern hemisphere population and finds about the same levels as Suguri found in Japan. Worthley was struck by large variations in Cs-137 burdens in different members of his own family, all of whom ate at the same table. Three reports from different parts of the world examined the cesium body burdens of Lapps and Eskimos who subsist on reindeer meat. Artic lichen have a high capacity to retain fallout. Adult reindeer eat 3-6 kg. of lichens a day and Lapps eat 1 kg/day of reindeer products.

Ellett and Brownell made a statistical study of the distribution of Cs-137 in a population. Meneely, Heyssel and their associates described variations in Cs-137 burden in a defined population sample. There are primary differences in burden which are clearly functions of age, sex, and race. However, even within a group of the same age, sex and race there are differences in burden commonly by as much as a factor of three, sometimes by a factor of six. Any effort to relate genetic or late somatic effects of ionizing radiation to the burden in a population must take into account the influence of race, sex, age, socioeconomic factors, geographic and meteorologic influences as well as wide individual variations within categories.

There are today only two uses of human whole-body counters that can be justified; these are 1) research and 2) monitoring of humans who may contain gamma-emitting isotope contamination. A third application-routine clinical testing-stands as a challenge to the instrument makers since, despite the many useful clinical tests that can be performed, the large expense of establishing and maintaining a purely clinical program could not be liquidated from reasonable charges to patients.

The proceedings of the second symposium on Radioactivity in man are in galley and will soon be published by Charles C. Thomas.

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RH 00302
BBC

"LASER RADIATION IN PHOTOCHEMISTRY"

The biological effects of lasers are currently receiving much attention. Although far-reaching changes are often produced, the complex nature of most biological systems makes detailed analysis of the results on a molecular basis difficult. In this research we are investigating the effect of laser radiation on selected simple chemical systems for which the absorption, energy transfer, and chemical processes may be elucidated. The results should aid the interpretation of biological irradiations, and may suggest new applications in this field.

The systems chosen for study are charge-transfer complexes, particularly those of aromatic donors with chloranil and tetracyanoethylene which absorb the 6940 Å radiation emitted by the ruby laser. The energy source consists of a pulsed ruby laser operating in the 100 to 1000 joules range; its application in this work constitutes monochromatic flash photolysis, a technique which offers many unique investigative possibilities in photochemistry and biology. Irradiation in the charge-transfer band results in specific transitions to excited singlet levels. Inter-system crossing to triplet levels can occur if the triplet state has a lower energy than the lowest excited singlet state. The consequences of the irradiation depend on the nature of the excited state and on the nature of the substrate. Apart from radiative and non-radiative decay to the ground state, interactions between excited states are possible at the intensities attainable with the laser. Chemical effects to be anticipated are dissociation into components with subsequent recombination, dimerization or more extensive polymerization, covalent bond formation between donor and acceptor, or addition, oxidation, and reduction reactions involving the substrate. Our plans call for examining the effects of variables such as substrate, concentration, temperature, and intensity with a number of complexes. The choice of solvent is particularly important not only because it can be involved in chemical reactions, but also because it can change the absorption characteristics and the equilibrium between the complex and its components.

The conventional techniques of flash photolysis serve for the detection of transient intermediates and for the study of emission characteristics. Kinetic data obtained from these measurements furnish the basis for the interpretation of the mechanisms of the interactions and decay processes. Products obtained in sufficient quantity by multiple flashing will be isolated by chromatographic techniques, and quantum yields will be measured by chemical actinometry and by direct intensity measurements. In selected cases, the effects of laser radiation and conventional irradiation will be compared.

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RH 00019	GREEN, Morris	89
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RH 00035	FETNER, Robert H.	16
RH 00039	da SILVA HORTA, Jorge	17
RH 00042	STRAIN, William	113
RH 00047	KUSCHNER, Marvin	18
RH 00050	COLEMAN, John S.	133
RH 00054	WILLIAMS, Edwin G.	96
RH 00061	GOLDBLITH, Samuel A.	19
RH 00063	LEONE, Charles A.	20
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RH 00193	SMITH, Walter T., Jr.	53
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BIRD, John T.	RH 00112	103
BOLING, Eldon A.	RH 00104	100
BURDETTE, Walter J.	RH 00116	49
BURNS, Charles H.	RH 00245	68
CALLOWAY, Doris H.	RH 00257	130
CHANG, M. C.	RH 00309	85
CLEGG, Marguerite D.	RH 00002	5
COLEMAN, John S.	RH 00050	133
da SILVA HORTA, Jorge	RH 00039	17
DAVIS, Robert E.	RH 00279	70
DAVIS, Roger T.	RH 00066	25
de HEVESY, George	RH 00186	52
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FETNER, Robert H.	RH 00035	16
FOYE, William O.	RH 00297	78
FRANKLIN, Ralph E.	RH 00124	124
FURCHTGOTT, Ernest	RH 00065	24
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GOLDMAN, Leon	RH 00024	13
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HERRANEN, Ailene	RH 00203	54
HEYSSEL, Robert M.	RH 00303	81
HIRAIZUMI, Yuichiro	RH 00034	15
HODGES, Paul	RH 00096	121
JOFTES, David L.	RH 00243	66
JOHNSTON, Francis J.	RH 00206	56
JOLLEY, Homer R.	RH 00252	106
KAUFMAN, Warren J.	RH 00079	119
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KUSCHNER, Marvin	RH 00047	18
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MARUYAMA, Yosh	RH 00107	62
MARUYAMA, Yosh	RH 00224	62
MENCZER, Leonard F.	RH 00260	107
MENEELY, George R.	RH 00229	134
MITTLER, Sidney	RH 00140	51
MORGAN, Russell H.	RH 00085	97
MORGAN, Russell H.	RH 00092	40
MUHLER, Joseph C.	RH 00114	47
OSBORNE, James W.	RH 00021	11
PENDLETON, Robert C.	RH 00030	95
PIHL, Alexander	RH 00098	44
PLUMMER, Gayther L.	RH 00117	123
RANKIN, John S., Jr.	RH 00073	114
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SELTSER, Raymond	RH 00075	32
SIGLER, William F.	RH 00077	118
SLOBODIAN, Evelyn S.	RH 00095	42
SMITH, Walter T., Jr.	RH 00193	53
SPENCER, Herta	RH 00222	63
SPERTI, George S.	RH 00204	55
STORER, John B.	RH 00071	29
STRAIN, William	RH 00042	113
TABACHNICK, Joseph	RH 00218	60
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KEYWORD INDEX

A Keyword-in-Context (KWIC) is a list of titles arranged alphabetically by keywords in the title of the projects. Keywords in the title are those which should describe the subject matter of the project. All keywords are arranged alphabetically in the Keyword Index, reading down the center of the page.

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 OXIDASES..LIPOXIDASE   BIOASSAY  RADIATION PROTECTION  DIET       RH-00238
RADIOISOTOPES..ZINC 65# BIOCHEMICAL STUDIES ON ENDOCRINE SYS       RH-00014
ION BEHAVIOR ACTIVITY   BIOCHEMISTRY  PHYSIOLOGY# LONG-TERM        RH-00072
E DEHYDROGENASE  ANIMAL BIOCHEMISTRY# X-RADIATION PROTECTION       RH-00089
LIDES IN FINNISH LAKES# BIOLOG /ENRICHMENT/ CHAINS OF RADION       RH-00307
ANIN CHEMICAL STRUCTURE BIOLOGICAL ACTIVITY  GAMMA GLOBULIN        RH-00063
SIS  CHEMICAL STRUCTURE BIOLOGICAL ACTIVITY A AMINO SULFIDES       RH-00300
ION  CHEMICAL STRUCTURE BIOLOGICAL ACTIVITY GUINEA PIGS  ISO       RH-00257
ANISMS  SLOW ELECTRONS# BIOLOGICAL EFFECTS OF LOW VELOCITY E       RH-00204
   NSITIVITY IN YEAST# BIOLOGICAL FACTORS AFFECTING RADIOSE        RH-00312
 OF RADIATION DAMAGE TO BIOLOGICAL MATERIALS RADIATION EFFEC       RH-00008
                 AMAGE# BIOLOGICAL MECHANISMS OF RADIATION D       RH-00367
T OF NEUTRON SPECTRA IN BIOLOGICAL SHIELDS# MEASUREMEN             RH-00253
DIATION EFFECTS  MARINE BIOLOGY  X RAYS  RADIOISOTOPES ECOLO       RH-00076
THOROTRAST THOROTRAST   BIOMETRY  BONE MARROW DISEASES  NEOP       RH-00039
 SCANNING CONFERENCES   BIOPHYSICS  RADIOGRAPHY EXTRACTION O       RH-00032
TOPES ECOLOGY..ANIMAL   BIOPHYSICS# RADIOBIOLOGICAL RESEARCH       RH-00076
CTS OF RADIUM ON STREAM BIOTA BELOW URANIUM MILLS RADIOISOTO       RH-00077
OPES..COBALT 60  SKIN   BLOOD CELLS CANCER CHEMOTHERAPY  RAD       RH-00024
NE GLUCOSE PHOSPHATES   BLOOD CELLS..ERYTHROCYTES  GUINEA PI       RH-00089
Y RADIATION  HEMOGLOBIN BLOOD CELLS..ERYTHROCYTES  RADIOLABE       RH-00186
ROGEN MUSTARDS THYMUS   BLOOD CELLS..LYMPHOCYTES  AMINO ACID       RH-00203
ES NEOPLASMS LEUKEMIA   BLOOD DONORS  RADIATION THERAPY LUNG       RH-00210
ITY  HISTOCOMPABILITY   BLOOD DONORS IMMUNOLOGY..ANTIGEN ANT       RH-00311
PLASMS ADENOCARCINOMA   BLOOD FLOW IMPEDANCE  DOSAGE  METAST       RH-00021
.WHOLE BODY RADIATION   BLOOD TRANSFUSION BONE MARROW  CHIME       RH-00311
 AGENTS  URINE  FECES   BLOOD..PLASMA  CALCIUM RETENTION  ME       RH-00222
ITION IN DISEASE STATES BODY COMPOSITION  HYPERTENSION..SYST       RH-00104
  RADIOLABELED BROMINE# BODY COMPOSITION IN DISEASE STATES B       RH-00104
   ACCURACY OF ASSAY BY BODY COUNTERS OF K-40 IN MAN#              RH-00283
ADIATION EFFECTS..WHOLE BODY RADIATION  ALFALFA  DIET FRACTI       RH-00257
ADIATION EFFECTS..WHOLE BODY RADIATION  BLOOD TRANSFUSION BO       RH-00311
ADIATION EFFECTS..WHOLE BODY RADIATION  ENZYME SUBSTRATE OXI       RH-00238
ADIATION EFFECTS..WHOLE BODY RADIATION  HEMOGLOBIN BLOOD CEL       RH-00186
ADIATION EFFECTS..WHOLE BODY RADIATION  NITROGEN MUSTARDS TH       RH-00203
ADIATION EFFECTS..WHOLE BODY RADIATION  RADIATION FALLOUT BR       RH-00091
ADIATION EFFECTS..WHOLE BODY RADIATION  X RAYS  AGE  LUNG RA       RH-00272
ADIATION EFFECTS..WHOLE BODY RADIATION  X RAYS  AGE SKELETON       RH-00094
ADIATION EFFECTS..WHOLE BODY RADIATION  X RAYS  CYSTAMINE RA       RH-00067
ADIATION EFFECTS..WHOLE BODY RADIATION# ENVIRONMENTAL EFFECT       RH-00037
AXIMAL INFORMATION FROM BODY SCANNING CONFERENCES  BIOPHYSIC       RH-00032
AXIMAL INFORMATION FROM BODY SCANNING# EXTRACTION OF MAXIMAL       RH-00032
Y  CYSTEAMINE DISULFIDE BONDS  GLUTATHIONE  ALBUMINS..SERUM        RH-00305
AL COMPLEXES  DISULFIDE BONDS  REACTION MECHANISMS RADIATION       RH-00297
ON SENSITIVITY CHEMICAL BONDS..BOND CLEAVAGE ELECTRON SPIN R       RH-00008
MUSCLE BONE NEOPLASMS   BONE  RADIOGRAPHY  MAMMAL  RATS META       RH-00090
CTURE..TEETH CHILDREN   BONE  SURVEY# TO STUDY RADIOACTIVE N       RH-00112
CONIUM CITRATE ON SR-89 BONE CANCER BONE..NEOPLASMS  ZIRCONI       RH-00139
 AGE SKELETON  GROWTH   BONE DENSITY  BONE WEIGHT  RATS LOCA       RH-00094
Y  RADIATION PROTECTION BONE MARROW  BONE MARROW PRESERVATIO       RH-00026
TION  BLOOD TRANSFUSION BONE MARROW  CHIMERAS  TYPING SERA         RH-00311
LS THYMIDINE  TRITIUM   BONE MARROW  5 IODODEOXYURIDINE CATA       RH-00099
 THOROTRAST  BIOMETRY   BONE MARROW DISEASES  NEOPLASMS LIVE       RH-00039
ROTECTION BONE MARROW   BONE MARROW PRESERVATION  CANCER CHE       RH-00026
METHODOLOGY# AUTOLOGOUS BONE MARROW PROTECTION AND CHEMOTHER       RH-00026
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HELATING AGENTS  MUSCLE BONE NEOPLASMS  BONE  RADIOGRAPHY  M          RH-00090
E NUCLIDES IN TEETH AND BONE RADIOISOTOPES..STRONTIUM 90  DE          RH-00112
SOTOPES..STRONTIUM 90   BONE RADIOLABELED CALCIUM  RADIOLABE          RH-00091
 GROWTH  BONE DENSITY   BONE WEIGHT  RATS LOCALIZED RADIATIO          RH-00004
TE ON SR-89 BONE CANCER BONE..NEOPLASMS  ZIRCONIUM CITRATE            RH-00139
       RADIOACTIVITY IN BOTTOM SEDIMENTS#                             RH-00369
ECTS  BETA RAYS  SKIN   BRADYKININ  AMINO ACID ENDOTHELIUM P          RH-00218
ELECTROLYTES  ENZYMES   BRAIN  RATS# EFFECTS OF IRRADIATION           RH-00078
TION  RADIATION FALLOUT BREMSSTRAHLUNG COUNTERS  RADIOISOTOP          RH-00091
D TRITIUM  RADIOLABELED BROMINE# BODY COMPOSITION IN DISEASE          RH-00104
SOPHARYNX HYPERPLASIA   BURSA  LYMPH NODES NEOPLASMS LEUKEMI          RH-00210
NETICS  MICE# EFFECT OF C-14 ON CYTOGENETICS RADIOISOTOPES..          RH-00243
M 90  BONE RADIOLABELED CALCIUM  RADIOLABELED COBALT RADIOLA          RH-00091
 FECES  BLOOD..PLASMA   CALCIUM RETENTION  METABOLISM  CLINI          RH-00222
TRY  X RAYS GAMMA RAYS# CALORIMETRIC MEASUREMENTS OF X- AND           RH-00105
RAPY  INSTRUMENTATION   CALORIMETRY  X RAYS GAMMA RAYS# CALO          RH-00105
HODONTICS RADIOGRAPHY   CAMERA..PINHOLE# A STUDY OF DESIGN C          RH-00113
S MOLECULAR STRUCTURE   CANCER  CHROMATOGRAPHY ULTRAVIOLET S          RH-00095
TY  RADIATION HAZARDS   CANCER AGE  RADIOLOGISTS# A STUDY OF          RH-00075
M CITRATE ON SR-89 BONE CANCER BONE..NEOPLASMS  ZIRCONIUM CI          RH-00139
T 60  SKIN  BLOOD CELLS CANCER CHEMOTHERAPY  RADIOMIMETIC AG          RH-00024
NO SULFIDES  BIOASSAY   CANCER CHEMOTHERAPY  THIONES RADIATI          RH-00300
E MARROW PRESERVATION   CANCER CHEMOTHERAPY CLINICAL STUDY            RH-00026
RATS# OCCUPATIONAL LUNG CANCER FROM IONIZING RADIATION RADIA          RH-00047
UDY OF IRRADIATED TINEA CAPITIS CASES# FOLLOW-UP ST                   RH-00298
 PROTECTION  BACTERIA   CARBOHYDRATES  EXTRACTS CHEMICAL STR          RH-00064
HOLE ANIMALS CONTAINING CARBON 14# AUTORADIOGRAPHY OF W               RH-00308
IRON  CARP RADIOLABELED CARBON# RADIOSENSITIVITY OF EXTRAMED          RH-00186
ED IRON  MATERNAL FETAL CARCINOGENESIS  CONGENITAL ABNORMALI          RH-00303
Y RADIOGRAPHY  GROWTH   CARCINOGENESIS  RATS..ALBINO CONGENI          RH-00086
 RADIATION PROTECTION   CARCINOGENESIS DOSAGE  MICE# EFFECTS          RH-00139
 EFFECTS  SQUAMOUS CELL CARCINOMA LUNG..NEOPLASMS  RADIOISOT          RH-00047
ES  RADIOLABELED IRON   CARP RADIOLABELED CARBON# RADIOSENSI          RH-00186
TS..ANIMALS NEOPLASMS   CATARACT  LEUKEMIA  SKELETON  AGING           RH-00081
ROW  5 IODODEOXYURIDINE CATARACT  MICE  ENERGY LEVELS  METAB          RH-00099
T CELLS AGING  PLANTS   CELL  SEEDS  RADIATION SENSITIVITY            RH-00294
ATION EFFECTS  SQUAMOUS CELL CARCINOMA LUNG..NEOPLASMS  RADI          RH-00047
  DEOXYRIBONUCLEIC ACID CELL COMPONENTS..CELL NUCLEUS  CELL           RH-00203
ASTS  GENETICS DOSAGE   CELL COMPONENTS..CELL WALL  INSTRUME          RH-00204
PONENTS..CELL NUCLEUS   CELL COMPONENTS..CYTOPLASM CELL COMP          RH-00203
L COMPONENTS..CYTOPLASM CELL COMPONENTS..MICROSOMES  ENZYMES          RH-00203
ION..MITOSIS KB CELLS   CELL CULTURE# X-RADIATION EFFECTS IN          RH-00035
FFECTS IN EUPLOID HUMAN CELL CULTURES RADIATION EFFECTS  X R          RH-00035
TY - METABOLIC STUDIES# CELL DIVISION CYCLE AND RADIOSENSITI          RH-00304
DIATION EFFECTS  GONADS CELL DIVISION..MEIOSIS  CELL DIVISIO          RH-00243
ELL DIVISION..MEIOSIS   CELL DIVISION..MITOSIS  GENETICS RAD          RH-00243
ATION EFFECTS  X RAYS   CELL DIVISION..MITOSIS KB CELLS  CEL          RH-00035
LL DIVISION..MITOSIS KB CELLS  CELL CULTURE# X-RADIATION EFF          RH-00035
LYSIS OF AGING IN PLANT CELLS AGING  PLANTS  CELL  SEEDS  RA          RH-00294
# IRRADIATION OF SINGLE CELLS BY ALPHA-PARTICLE MICROBEAM AL          RH-00002
.COBALT 60  SKIN  BLOOD CELLS CANCER CHEMOTHERAPY  RADIOMIME          RH-00024
S  SPLEEN  THYMUS  GERM CELLS THYMIDINE  TRITIUM  BONE MARRO          RH-00099
FERENTIAL RESISTANCE OF CELLS TO IRRADIATION# DIF                     RH-00325
UCOSE PHOSPHATES  BLOOD CELLS..ERYTHROCYTES  GUINEA PIGS DEH          RH-00089
ATION  HEMOGLOBIN BLOOD CELLS..ERYTHROCYTES  RADIOLABELED IR          RH-00186
 MUSTARDS THYMUS  BLOOD CELLS..LYMPHOCYTES  AMINO ACID RIBON          RH-00203
E STUDIES IN IRRADIATED CELLS# REACTIVE LIFETIM                       RH-00340
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  CHROMATOGRAPHY  ULTRA CENTRIFUGATION ELECTROPHORESIS  SPEC       RH-00124
FECTS ON THE CONTENT OF CESIUM-137 IN MILK RADIATION FALLOUT       RH-00030
ES# BIOLOG /ENRICHMENT/ CHAINS OF RADIONUCLIDES IN FINNISH L       RH-00307
ION COUNTERS IONIZATION CHAMBERS  BACKGROUND RADIATION  WATE       RH-00054
 DECONTAMINATION  METAL CHELATES  AMINO ACID ORAL# COMPOUNDS       RH-00042
SOTOPES..STRONTIUM 90   CHELATING AGENTS  MUSCLE BONE NEOPLA       RH-00090
HYROID HORMONES CITRATE CHELATING AGENTS  URINE  FECES  BLOO       RH-00222
 METABOLISM# EFFECTS OF CHELATING AGENTS ON RADIOSTRONTIUM E       RH-00090
MS  ZIRCONIUM CITRATE   CHELATING AGENTS RADIOISOTOPES..STRO       RH-00139
RADIATION PROTECTION BY CHEMICAL AGENTS IN GUINEA PIGS RADIA       RH-00089
  RADIATION SENSITIVITY CHEMICAL BONDS..BOND CLEAVAGE ELECTR       RH-00008
S LOCALIZED RADIATION   CHEMICAL COMPOSITION# RELATION OF AG       RH-00004
      DIATION REACTION# CHEMICAL MODIFICATION OF REGIONAL RA       RH-00224
PROTECTION DRUGS# LOCAL CHEMICAL RADIATION PROTECTION IN MIC       RH-00268
CARBOHYDRATES  EXTRACTS CHEMICAL STRUCTURE  METABOLITES  MET       RH-00064
ONAL GROUPS SYNTHESIS   CHEMICAL STRUCTURE BIOLOGICAL ACTIVI       RH-00300
ION EFFECTS  HEMOCYANIN CHEMICAL STRUCTURE BIOLOGICAL ACTIVI       RH-00063
A  DIET FRACTIONATION   CHEMICAL STRUCTURE BIOLOGICAL ACTIVI       RH-00257
LANOGASTER# ANTIMITOTIC CHEMICALS AS PROTECTION AGAINST RADI       RH-00140
TROPHOTOMETRY  PHYSICAL CHEMISTRY  INTERFACE# RADIATION EFFE       RH-00206
GS  SYNTHESIS  PHYSICAL CHEMISTRY IMINES# ALPHA-AMINO MERCAP       RH-00300
CHIMERAS  TYPING SERA   CHEMOTHERAPY  PRIMATES MALABSORPTION       RH-00311
HEMATOPOIETIC TISSUES   CHEMOTHERAPY  RADIATION SENSITIVITY        RH-00239
KIN  BLOOD CELLS CANCER CHEMOTHERAPY  RADIOMIMETIC AGENTS  C       RH-00024
FIDES  BIOASSAY  CANCER CHEMOTHERAPY  THIONES RADIATION PROT       RH-00300
OW PRESERVATION  CANCER CHEMOTHERAPY CLINICAL STUDY  ANIMAL        RH-00026
E MARROW PROTECTION AND CHEMOTHERAPY NEOPLASMS  RADIATION TH       RH-00026
 CULTURE  FIBROBLASTS   CHICKENS ELECTRON MICROSCOPY# IRRADI       RH-00002
TUDINAL STUDY  SURVEY   CHILDREN  ADULTS RETICULOENDOTHELIOS       RH-00210
DENTAL STRUCTURE..TEETH CHILDREN  BONE  SURVEY# TO STUDY RAD       RH-00112
Y  LONGITUDINAL STUDY   CHILDREN  COMPUTER PRENATAL INFLUENC       RH-00303
IATION EFFECTS  FETUS   CHILDREN  LONGITUDINAL STUDY PREGNAN       RH-00207
ADIOGRAPHY# ANALYSIS OF CHILDREN RADIATED EARLY IN FETAL LIF       RH-00207
THELIOSIS# NEOPLASMS IN CHILDREN TREATED WITH X-RAYS RADIATI       RH-00210
ANSFUSION BONE MARROW   CHIMERAS  TYPING SERA  CHEMOTHERAPY        RH-00311
 EFFECTS NAPHTHALENES   CHLORIDES  IONIZATION  PEROXIDES MIC       RH-00061
.TOBACCO MOSAIC VIRUS   CHROMATOGRAPHY  HUMAN ELECTROPHORESI       RH-00063
 ELECTROPHORESIS COLUMN CHROMATOGRAPHY  RABBITS# EFFECT OF X       RH-00203
MECHANISMS ION EXCHANGE CHROMATOGRAPHY  SUBSTRATE# CHARACTER       RH-00257
PLANTS MICROORGANISMS   CHROMATOGRAPHY  ULTRA CENTRIFUGATION       RH-00124
IONIZING RADIATION  GAS CHROMATOGRAPHY SPECTROPHOTOMETRY  PH       RH-00206
LAR STRUCTURE  CANCER   CHROMATOGRAPHY ULTRAVIOLET SPECTROME       RH-00095
 CYTOLOGY METHODOLOGY   CHROMOSOME ABERRATIONS# CYTOLOGICAL        RH-00294
AL STUDY# X-RAY INDUCED CHROMOSOME CHANGES IN MAN X RAYS  RA       RH-00024
      N GENODERMATOSES# CHROMOSOMES AFTER SCALP X-RAYS AND I       RH-00299
SEASES  NEOPLASMS LIVER CIRRHOSIS  NERVOUS SYSTEM DISORDERS        RH-00039
ENSION..SYSTEMIC  LIVER CIRRHOSIS MALNUTRITION  OBESITY  RAD       RH-00104
E..NEOPLASMS  ZIRCONIUM CITRATE  CHELATING AGENTS RADIOISOTO       RH-00139
S  PARATHYROID HORMONES CITRATE CHELATING AGENTS  URINE  FEC       RH-00222
E# EFFECTS OF ZIRCONIUM CITRATE ON SR-89 BONE CANCER BONE..N       RH-00139
TY CHEMICAL BONDS..BOND CLEAVAGE ELECTRON SPIN RESONANCE SPE       RH-00008
                  RAPY# CLINICAL DOSIMETRY FOR COBALT-60 THE       RH-00045
ON  CANCER CHEMOTHERAPY CLINICAL STUDY  ANIMAL  METHODOLOGY#       RH-00026
  RADIOLABELED SODIUM   CLINICAL STUDY RADIOLABELED TRITIUM        RH-00104
TICHANNEL ANALYZER  AGE CLINICAL STUDY# DOSE DISTRIBUTIONS I       RH-00085
RETENTION  METABOLISM   CLINICAL STUDY# STUDIES OF RADIOSTRO       RH-00222
OLID STATE..CHEMISTRY   CLINICAL STUDY# THERMOLUMINESCENT DO       RH-00137
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 RADIOMIMETIC AGENTS    CLINICAL STUDY# X-RAY INDUCED CHROMO     RH-00024
DUOUS TEETH IN THE GULF COAST AREA DENTAL STRUCTURE TEETH  R     RH-00252
D CALCIUM  RADIOLABELED COBALT RADIOLABELED STRONTIUM  RADIO     RH-00091
 CLINICAL DOSIMETRY FOR COBALT-60 THERAPY#                       RH-00045
ES  MUTATIONS  X RAYS   COLCHICINE URETHAN  B AZAGUANINE  6      RH-00140
S BACTERIA..ESCHERICHIA COLI  FUNGI..YEASTS  GENETICS DOSAGE     RH-00204
         IDES IN WATER# COLLOID-SOLUTE SORBTION OF RADIONUCL     RH-00183
USPENSIONS..CHEMISTRY   COLLOIDS SOLUTIONS  ELECTRODES  ULTR     RH-00206
E  ZONE ELECTROPHORESIS COLUMN CHROMATOGRAPHY  RABBITS# EFFE     RH-00203
AL RADIATION HYGIENE IN COMMUNITY RADIATION PROTECTION  X RA     RH-00260
XYRIBONUCLEIC ACID CELL COMPONENTS..CELL NUCLEUS  CELL COMPO     RH-00203
  GENETICS DOSAGE  CELL COMPONENTS..CELL WALL  INSTRUMENTATI     RH-00204
NTS..CELL NUCLEUS  CELL COMPONENTS..CYTOPLASM CELL COMPONENT     RH-00203
PONENTS..CYTOPLASM CELL COMPONENTS..MICROSOMES  ENZYMES SUBS     RH-00203
DING  INSTRUMENTATION   COMPUTER ANALYSIS# ABSORBED RADIATIO     RH-00003
DINAL STUDY  CHILDREN   COMPUTER PRENATAL INFLUENCES# PRENAT     RH-00303
      PROBLEMS# DIGITAL COMPUTING TECHNIQUES IN RADIOLOGICAL     RH-00286
 RADIATION..UNSPECIFIED CONDITIONING  BEHAVIOR  VAGOTOMY  NE     RH-00068
TION FROM BODY SCANNING CONFERENCES  BIOPHYSICS  RADIOGRAPHY     RH-00032
S OF RADIATION RESEARCH CONFERENCES..INTERNATIONAL MEETINGS      RH-00050
US  AGE  SEX DIFFERENCE CONGENITAL ABNORMALITIES  FERTILITY      RH-00097
 FETAL CARCINOGENESIS   CONGENITAL ABNORMALITIES  MORBIDITY      RH-00303
NOGENESIS  RATS..ALBINO CONGENITAL ABNORMALITIES# EFFECTS OF     RH-00086
H# SECOND INTERNATIONAL CONGRESS OF RADIATION RESEARCH CONFE     RH-00050
TS SECOND INTERNATIONAL CONGRESS OF RADIATION RESEARCH# SECO     RH-00050
WATER SUPPLY  SOIL FOOD CONTAMINATION  GEOGRAPHICAL SITES..F     RH-00054
UPATIONAL HAZARDS  FOOD CONTAMINATION RADIATION DECONTAMINAT     RH-00173
ONMENTAL EFFECTS ON THE CONTENT OF CESIUM-137 IN MILK RADIAT     RH-00030
 SODIUM SULFATE ADRENAL CORTEX HORMONES  PARATHYROID HORMONE     RH-00222
US SYSTEM  RATS ADRENAL CORTEX HORMONES  PHYSIOLOGY# PHYSIOL     RH-00068
 RADIOGRAPHY  RADIATION COUNTERS  EPIDEMIOLOGY  DOSAGE STATI     RH-00092
 FALLOUT BREMSSTRAHLUNG COUNTERS  RADIOISOTOPES..STRONTIUM 9     RH-00091
C..TESTS  SCINTILLATION COUNTERS GONADS  DOSAGE  PHANTOM MOD     RH-00084
SAMPLING  SCINTILLATION COUNTERS IONIZATION CHAMBERS  BACKGR     RH-00054
CURACY OF ASSAY BY BODY COUNTERS OF K-40 IN MAN# AC              RH-00283
 METABOLISM# WHOLE-BODY COUNTING OF RADIOACTIVITY IN HUMANS      RH-00091
SH RADIOACTIVE WASTES   CRUSTACEANS  MOLLUSKS  MONITORING# R     RH-00074
DIATION EFFECTS  TISSUE CULTURE  FIBROBLASTS  CHICKENS ELECT     RH-00002
.MITOSIS KB CELLS  CELL CULTURE# X-RADIATION EFFECTS IN EUPL     RH-00035
S IN EUPLOID HUMAN CELL CULTURES RADIATION EFFECTS  X RAYS       RH-00035
 STUDIES# CELL DIVISION CYCLE AND RADIOSENSITIVITY - METABOL     RH-00304
LBUMINS..SERUM ALBUMINS CYSTAMINE  DEHYDROGENASES..ALCOHOL D     RH-00305
ODY RADIATION  X RAYS   CYSTAMINE RADIATION PROTECTION  CYST     RH-00067
 RADIATION PROTECTION   CYSTEAMINE  AET  MATERNAL FETAL BEHA     RH-00067
ION PROTECTION X RAYS   CYSTEAMINE  BEHAVIOR  MENTAL RETARDA     RH-00306
FFECTS MORBIDITY  AET   CYSTEAMINE  P AMINOPROPRIOPHENONE  M     RH-00268
MY PRENATAL INFLUENCES# CYSTEAMINE AND X-RAYS PRENATALLY, BE     RH-00306
RADIATION SENSITIVITY   CYSTEAMINE DISULFIDE BONDS  GLUTATHI     RH-00305
ES  ENZYMES SUBSTRATE   CYSTEAMINE SEROTININ  HISTAMINE  ZON     RH-00203
ETICS RADIOAUTOGRAPHY   CYTOGENETICS  MICE# EFFECT OF C-14 O     RH-00243
MICE# EFFECT OF C-14 ON CYTOGENETICS RADIOISOTOPES..CARBON 1     RH-00243
CHROMOSOME ABERRATIONS# CYTOLOGICAL ANALYSIS OF AGING IN PLA     RH-00294
GENETICS..CHROMOSOMES   CYTOLOGY METHODOLOGY  CHROMOSOME ABE     RH-00294
R. STUDIES OF RADIATION DAMAGE IN BIO-MATERIALS# E.S.            RH-00288
ON IN PRIMARY RADIATION DAMAGE IONIZING RADIATION  RADIATION     RH-00245
SR STUDIES OF RADIATION DAMAGE RADIATION SENSITIVITY  SULFHY     RH-00098
Y# STUDIES OF RADIATION DAMAGE TO BIOLOGICAL MATERIALS RADIA     RH-00008
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MECHANISMS OF RADIATION DAMAGE# BIOLOGICAL                              RH-00367
 LIFE SPAN IN RADIATION DAMAGED MICE RADIATION EFFECTS  AGE             RH-00071
O  MONITORING# SR-90 IN DECIDUOUS TEETH IN THE GULF COAST AR            RH-00252
RADIOISOTOPES RADIATION DECONTAMINATION  METAL CHELATES  AMI            RH-00042
CONTAMINATION RADIATION DECONTAMINATION  RADIOISOTOPES..IODI            RH-00173
EXCHANGE FOR HIGH-ORDER DECONTAMINATION RADIOACTIVE WASTES              RH-00079
NASES..PHOSPHOGLUCONATE DEHYDROGENASE  ANIMAL BIOCHEMISTRY#             RH-00089
DEHYDROGENASES..ALCOHOL DEHYDROGENASE  THIOLS SYNTHESIS  RAD            RH-00305
UM ALBUMINS CYSTAMINE   DEHYDROGENASES..ALCOHOL DEHYDROGENAS            RH-00305
YTHROCYTES  GUINEA PIGS DEHYDROGENASES..PHOSPHOGLUCONATE DEH            RH-00089
ON  RADIATION EFFECTS   DEHYDROGENATION FLAVIN MONONUCLEOTID            RH-00245
OGY..ANTIGENS  PROTEINS DENATURATION  GAMMA RAYS MOLECULAR S            RH-00063
 SKELETON  GROWTH  BONE DENSITY  BONE WEIGHT  RATS LOCALIZED            RH-00064
ON PROTECTION  X RAYS   DENTAL PERSONNEL  HARTFORD GEOGRAPHI            RH-00269
  METHODOLOGY# LEVEL OF DENTAL RADIATION HYGIENE IN COMMUNIT            RH-00269
 IN THE GULF COAST AREA DENTAL STRUCTURE TEETH  RADIOASSAY              RH-00252
SOTOPES..STRONTIUM 90   DENTAL STRUCTURE..TEETH CHILDREN  BO            RH-00112
DY OF DESIGN CHANGES IN DENTAL X-RAY MACHINES RADIATION PROT            RH-00113
ON PROTECTION  X RAYS   DENTISTRY..ORTHODONTICS RADIOGRAPHY             RH-00113
ACID ULTRAVIOLET RAYS   DEOXYRIBONUCLEIC ACID  MICROORGANISM            RH-00221
ACID RIBONUCLEIC ACID   DEOXYRIBONUCLEIC ACID CELL COMPONENT            RH-00203
-IRRADIATION EFFECTS ON DERMAL VASCULAR PERMEABILITY RADIATI            RH-00218
ONADAL RADIATION DURING DERMATOLOGIC X RAY THERAPY GONADS  R            RH-00258
OLUMINESCENCE RADIATION DETECTOR PHANTOM MODELS  INSTRUMENTA            RH-00137
 90 EFFECTS ON PULP AND DEVELOPING TEETH# STRONTIUM                     RH-00343
G PATIENT DOSE IN X-RAY DIAGNOSIS X RAYS  RADIOGRAPHY  DOSAG            RH-00096
# DOSE DISTRIBUTIONS IN DIAGNOSTIC X-RAY PROCEDURES X RAYS              RH-00085
POSURE TO GONADS DURING DIAGNOSTIC XRAY RADIOGRAPHY  DIAGNOS            RH-00084
STIC XRAY RADIOGRAPHY   DIAGNOSTIC..TESTS  SCINTILLATION COU            RH-00084
 RADIATION PROTECTION   DIET AGING  SEX DIFFERENCE  METHODOL            RH-00239
DY RADIATION  ALFALFA   DIET FRACTIONATION  CHEMICAL STRUCTU            RH-00257
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ATES BODY COMPOSITION	HYPERTENSION..SYSTEMIC LIVER CIRRHO	RH-00104
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D METABOLISM STUDIES OF	I-131 AND SR-90# ALTERE	RH-00211
SIS PHYSICAL CHEMISTRY	IMINES# ALPHA-AMINO MERCAPTANS AND A	RH-00300
IMALS IMMUNOLOGY..CROSS	IMMUNITY HISTOCOMPABILITY BLOOD DO	RH-00311
MPABILITY BLOOD DONORS	IMMUNOLOGY..ANTIGEN ANTIBODY REACTIO	RH-00311
ACROMOLECULES BINDING	IMMUNOLOGY..ANTIGEN ANTIBODY REACTIO	RH-00005
NS BY GAMMA-IRRADIATION	IMMUNOLOGY..ANTIGENS PROTEINS DENAT	RH-00063
TATION IN LARGE ANIMALS	IMMUNOLOGY..CROSS IMMUNITY HISTOCOM	RH-00311
NOCARCINOMA BLOOD FLOW	IMPEDANCE DOSAGE METASTASIS RATS	RH-00021
DIOGENIC SEIZURE NERVE	IMPULSE TRANSMISSION RATS SENSORY D	RH-00306
TRAVIOLET SPECTROMETRY#	INACTIVATIONS OF ENZYMES BY IONIZING	RH-00095
ABSORBED RADIATION DOSE	INCIDENT TO FLUOROSCOPIC PROCEDURES	RH-00003
FECTS X RAYS EMBRYO	INFANTS..ANIMALS NEOPLASMS CATARACT	RH-00081
IATION EFFECTS FETUS	INFANTS..ANIMALS..NEWBORN BEHAVIOR	RH-00065
RADIATION SENSITIVITY	INFECTIOUS DISEASES MICE# RADIATION	RH-00239
ADRENALECTOMY PRENATAL	INFLUENCES# CYSTEAMINE AND X-RAYS PR	RH-00306
DREN COMPUTER PRENATAL	INFLUENCES# PRENATAL EXPOSURE TO RAD	RH-00303
# EXTRACTION OF MAXIMAL	INFORMATION FROM BODY SCANNING CONFE	RH-00032
Y EXTRACTION OF MAXIMAL	INFORMATION FROM BODY SCANNING# EXTR	RH-00032
FEX RADIATION HAZARDS	INLAND FRESH WATERS ECOLOGY..ANIMAL	RH-00215
ION RADIATION THERAPY	INSTRUMENTATION CALORIMETRY X RAYS	RH-00105
ELECTRONIC RECORDING	INSTRUMENTATION COMPUTER ANALYSIS#	RH-00003
RADIOGRAPHY DOSAGE	INSTRUMENTATION METHODOLOGY RADIATIO	RH-00096
TECTOR PHANTOM MODELS	INSTRUMENTATION METHODOLOGY SOLID ST	RH-00137
COMPONENTS..CELL WALL	INSTRUMENTATION RADIATION EFFECTS M	RH-00204
MICROBEAM RADIATION	INSTRUMENTATION RADIATION EFFECTS T	RH-00002
NOL# MERCAPTO-DISULFIDE	INTERCHANGE IN RADIOPROTECTION RADIA	RH-00305
Y PHYSICAL CHEMISTRY	INTERFACE# RADIATION EFFECTS IN HETE	RH-00206
ADIATION EFFECTS SECOND	INTERNATIONAL CONGRESS OF RADIATION	RH-00050
IATION RESEARCH# SECOND	INTERNATIONAL CONGRESS OF RADIATION	RH-00050
N SENSITIVITY X RAYS	INTESTINAL NEOPLASMS ADENOCARCINOMA	RH-00021
RRADIATION ON THE SMALL	INTESTINE RADIATION SENSITIVITY X R	RH-00021
NORMALITIES# EFFECTS OF	INUTERO IRRADIATION OF THE RAT RADIA	RH-00086
TRITIUM BONE MARROW 5	IODODEOXYURIDINE CATARACT MICE ENE	RH-00099
ON REACTION MECHANISMS	ION EXCHANGE CHROMATOGRAPHY SUBSTRA	RH-00257
RADIATION PROTECTION#	ION EXCHANGE FOR HIGH-ORDER DECONTAM	RH-00079
PHTHALENES CHLORIDES	IONIZATION PEROXIDES MICROORGANISMS	RH-00061
SCINTILLATION COUNTERS	IONIZATION CHAMBERS BACKGROUND RADI	RH-00054
YS SURFACE PROPERTIES	IONIZING RADIATION GAS CHROMATOGRAP	RH-00206
MEDULLAR ERYTHROPOIESIS	IONIZING RADIATION HEMATOPOIESIS..E	RH-00186
RADIATIONS SANITATION	IONIZING RADIATION RADIATION EFFEC	RH-00061
RIMARY RADIATION DAMAGE	IONIZING RADIATION RADIATION EFFECT	RH-00245
S & ZYGOTES# EFFECTS OF	IONIZING RADIATION ON MAMMALIAN GAME	RH-00309
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THERAPY SKIN DISEASES	IONIZING RADIATION..UNSPECIFIED RAD	RH-00258
IOR RADIATION HAZARDS	IONIZING RADIATION..UNSPECIFIED COND	RH-00068
M OF PROTECTION AGAINST	IONIZING RADIATION# MECHANIS	RH-00106
VEMENT IN SANITATION BY	IONIZING RADIATIONS SANITATION IONI	RH-00061

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THROCYTES  RADIOLABELED IRON  CARP RADIOLABELED CARBON# RADI          RH-00186
N EFFECTS  RADIOLABELED IRON  MATERNAL FETAL CARCINOGENESIS           RH-00303
EXPOSURE TO RADIOACTIVE IRON, AFTER FIFTEEN YEARS RADIATION           RH-00303
      S# AGING IN X-RAY IRRADIATED AND NON-IRRADIATED MONKEY          RH-00066
IVE LIFETIME STUDIES IN IRRADIATED CELLS# REACT                       RH-00340
ETABOLISM IN NORMAL AND IRRADIATED LENSES PROTEINS  EYE..LEN          RH-00019
ETABOLISM IN NORMAL AND IRRADIATED LENSES# PROTEIN M                  RH-00345
     FOLLOW-UP STUDY OF IRRADIATED TINEA CAPITIS CASES#               RH-00298
OMES  METABOLISM  DOGS# IRRADIATION AND MARROW TRANSPLANTATI          RH-00311
NS ELECTRON MICROSCOPY# IRRADIATION OF SINGLE CELLS BY ALPHA          RH-00002
     KIDNEY# EFFECTS OF IRRADIATION OF THE EXTERIORIZED RAT           RH-00336
IES# EFFECTS OF INUTERO IRRADIATION OF THE RAT RADIATION EFF          RH-00086
BRAIN  RATS# EFFECTS OF IRRADIATION ON AGING OF SMALL ANIMAL          RH-00078
AL VS DIRECT EFFECTS OF IRRADIATION ON MAMMALS# ANCESTR               RH-00328
YGENES IN DROSOPHILA BY IRRADIATION RADIATION EFFECTS  DROSO          RH-00062
 RESISTANCE OF CELLS TO IRRADIATION# DIFFERENTIAL                     RH-00325
 ACTIVITY GUINEA PIGS   ISOLATION PURIFICATION  REACTION MEC          RH-00257
SAY BY BODY COUNTERS OF K-40 IN MAN# ACCURACY OF AS                   RH-00283
 CELL DIVISION..MITOSIS KB CELLS  CELL CULTURE# X-RADIATION           RH-00035
OF THE EXTERIORIZED RAT KIDNEY# EFFECTS OF IRRADIATION                RH-00336
ADIONUCLIDES IN FINNISH LAKES# BIOLOG /ENRICHMENT/ CHAINS OF          RH-00307
TRUCTURE TRIPLET STATE# LASER RADIATION IN PHOTOCHEMISTRY PH          RH-00302
UNDS  RADIATION EFFECTS LASERS  MOLECULAR ENERGY LEVELS  MOL          RH-00302
  EMOTIONAL REACTIONS   LEARNING  AGING  GENETICS LONGITUDIN          RH-00065
 AET AND DISCRIMINATION LEARNING IN X-IRRADIATED RATS RADIAT          RH-00067
N NORMAL AND IRRADIATED LENSES PROTEINS  EYE..LENS  EYE..LEN          RH-00019
N NORMAL AND IRRADIATED LENSES# PROTEIN METABOLISM I                  RH-00345
  LYMPH NODES NEOPLASMS LEUKEMIA  BLOOD DONORS  RADIATION TH          RH-00210
S NEOPLASMS  CATARACT   LEUKEMIA  SKELETON  AGING  MICE RADI          RH-00081
VOUS SYSTEM DISORDERS   LEUKEMIA GRANULOMA  RADIOGRAPHY# RES          RH-00039
SOTOPES..STRONTIUM 90   LICHENS MOSS  SOIL  WATER SUPPLY  EC          RH-00117
RADIATED EARLY IN FETAL LIFE RADIATION EFFECTS  FETUS  CHILD          RH-00207
  MICE# REPAIR RATE AND LIFE SPAN IN RADIATION DAMAGED MICE           RH-00071
             # REACTIVE LIFETIME STUDIES IN IRRADIATED CELLS          RH-00340
ADIOACTIVE ACCUMULATION LIMITS IN EDIBLE SHELLFISH RADIOACTI          RH-00074
SATURATED FATTY ACIDS   LIPID PEROXIDES  PEROXIDATION RADIAT          RH-00238
ROW DISEASES  NEOPLASMS LIVER CIRRHOSIS  NERVOUS SYSTEM DISO          RH-00039
YPERTENSION..SYSTEMIC   LIVER CIRRHOSIS MALNUTRITION  OBESIT          RH-00104
ATION PROTECTION DRUGS# LOCAL CHEMICAL RADIATION PROTECTION           RH-00268
SITY  BONE WEIGHT  RATS LOCALIZED RADIATION  CHEMICAL COMPOS          RH-00004
OCHEMISTRY  PHYSIOLOGY# LONG-TERM RADIATION EFFECTS ON SUBHU          RH-00072
OSOPHILA MELANOGASTER   LONGEVITY  FERTILITY ECOLOGY..ANIMAL          RH-00034
ERENCE  GENETIC STRAINS LONGEVITY  MICE# REPAIR RATE AND LIF          RH-00071
  MORBIDITY MORTALITY   LONGITUDINAL STUDY  CHILDREN  COMPUT          RH-00303
ARNING  AGING  GENETICS LONGITUDINAL STUDY  RATS..ALBINO  VI          RH-00065
NORS  RADIATION THERAPY LONGITUDINAL STUDY  SURVEY  CHILDREN          RH-00210
ECTS  FETUS  CHILDREN   LONGITUDINAL STUDY PREGNANCY  RADIOG          RH-00207
FFECTS  X RAYS  FETUS   LONGITUDINAL STUDY RADIOGRAPHY  GROW          RH-00086
LAVIN MONONUCLEOTIDES   LUMINESCENCE..BIOLUMINESCENCE BACTER          RH-00245
PHY  RATS# OCCUPATIONAL LUNG CANCER FROM IONIZING RADIATION           RH-00047
ADIATION  X RAYS  AGE   LUNG RADIATION SENSITIVITY  CRITERIA          RH-00272
SQUAMOUS CELL CARCINOMA LUNG..NEOPLASMS  RADIOISOTOPES..RUTH          RH-00047
NX HYPERPLASIA  BURSA   LYMPH NODES NEOPLASMS LEUKEMIA  BLOO          RH-00210
 RADIOMIMETIC AGENTS ON LYMPHOCYTES RADIATION EFFECTS..WHOLE          RH-00203
CHANGES IN DENTAL X-RAY MACHINES RADIATION PROTECTION  X RAY          RH-00113
SOTOPES..STRONTIUM 85   MAGNESIUM  SODIUM SULFATE ADRENAL CO          RH-00222
FLUOROSCOPY  STATISTICS MAGNETIC RECORDING SYSTEM  MULTICHAN          RH-00085
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  CHEMOTHERAPY  PRIMATES MALABSORPTION SYNDROMES  METABOLISM        RH-00311
STEMIC  LIVER CIRRHOSIS MALNUTRITION  OBESITY  RADIOLABELED         RH-00104
MS  BONE  RADIOGRAPHY   MAMMAL  RATS METABOLISM# EFFECTS OF         RH-00090
F IONIZING RADIATION ON MAMMALIAN GAMETES & ZYGOTES# EFFECTS        RH-00309
ADIATION SENSITIVITY OF MAMMALS RADIATION EFFECTS..WHOLE BOD        RH-00272
FECTS OF IRRADIATION ON MAMMALS# ANCESTRAL VS DIRECT EF             RH-00328
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       RADIOACTIVITY IN MAN SECOND SYMPOSIUM#                       RH-00229
D CHROMOSOME CHANGES IN MAN X RAYS  RADIATION EFFECTS  GENET        RH-00024
ODY COUNTERS OF K-40 IN MAN# ACCURACY OF ASSAY BY B                 RH-00283
SMS RADIATION EFFECTS   MARINE BIOLOGY  X RAYS  RADIOISOTOPE        RH-00076
STERS# RADIOACTIVITY IN MARINE ORGANISMS MOLLUSKS  TUNICATES        RH-00073
OBIOLOGICAL RESEARCH ON MARINE ORGANISMS RADIATION EFFECTS          RH-00076
DIATION PROTECTION BONE MARROW  BONE MARROW PRESERVATION  CA        RH-00026
 BLOOD TRANSFUSION BONE MARROW  CHIMERAS  TYPING SERA  CHEMO        RH-00311
HYMIDINE  TRITIUM  BONE MARROW  5 IODODEOXYURIDINE CATARACT         RH-00099
ROTRAST  BIOMETRY  BONE MARROW DISEASES  NEOPLASMS LIVER CIR        RH-00039
CTION BONE MARROW  BONE MARROW PRESERVATION  CANCER CHEMOTHE        RH-00026
DOLOGY# AUTOLOGOUS BONE MARROW PROTECTION AND CHEMOTHERAPY N        RH-00026
  DOGS# IRRADIATION AND MARROW TRANSPLANTATION IN LARGE ANIM        RH-00311
LY, BEHAVIOR OF THE RAT MATERNAL FETAL  RADIATION EFFECTS  R        RH-00306
TION  CYSTEAMINE  AET   MATERNAL FETAL BEHAVIOR  PSYCHOLOGIC        RH-00067
TS  RADIOLABELED IRON   MATERNAL FETAL CARCINOGENESIS  CONGE        RH-00303
SCANNING# EXTRACTION OF MAXIMAL INFORMATION FROM BODY SCANNI        RH-00032
DIOGRAPHY EXTRACTION OF MAXIMAL INFORMATION FROM BODY SCANNI        RH-00032
FERENCES..INTERNATIONAL MEETINGS  RADIATION EFFECTS SECOND I        RH-00050
TION EFFECTS DROSOPHILA MELANOGASTER  LONGEVITY  FERTILITY E        RH-00034
RMATOGENESIS DROSOPHILA MELANOGASTER# ANTIMITOTIC CHEMICALS         RH-00140
 CYSTEAMINE  BEHAVIOR   MENTAL RETARDATION  FETUS AUDIOGENIC        RH-00306
TRY IMINES# ALPHA-AMINO MERCAPTANS AND ALPHA-AMINO SULFIDES         RH-00300
SMS  2 MERCAPTOETHANOL# MERCAPTO-DISULFIDE INTERCHANGE IN RA        RH-00305
 REACTION MECHANISMS  2 MERCAPTOETHANOL# MERCAPTO-DISULFIDE         RH-00305
RETHAN  8 AZAGUANINE  6 MERCAPTOPURINE  SPERMATOGENESIS DROS        RH-00140
AND RADIOSENSITIVITY -  METABOLIC STUDIES# CELL DIVISION CYC        RH-00304
TRUCTURE  METABOLITES   METABOLISM  ANIMAL# RADIATION-RESIST        RH-00064
MA  CALCIUM RETENTION   METABOLISM  CLINICAL STUDY# STUDIES         RH-00222
LABSORPTION SYNDROMES   METABOLISM  DOGS# IRRADIATION AND MA        RH-00311
UDIES OF RADIOSTRONTIUM METABOLISM AND REMOVAL IN MAN RADIOI        RH-00222
        LENSES# PROTEIN METABOLISM IN NORMAL AND IRRADIATED         RH-00345
ATS METABOLISM# PROTEIN METABOLISM IN NORMAL AND IRRADIATED         RH-00019
             O# ALTERED METABOLISM STUDIES OF I-131 AND SR-9        RH-00211
DIOGRAPHY  MAMMAL  RATS METABOLISM# EFFECTS OF CHELATING AGE        RH-00090
IDS  RADIOLABELED  RATS METABOLISM# PROTEIN METABOLISM IN NO        RH-00019
  MICE  ENERGY LEVELS   METABOLISM# RBE OF MONOENERGETIC NEU        RH-00099
 METHODOLOGY  RETENTION METABOLISM# WHOLE-BODY COUNTING OF R        RH-00091
TS CHEMICAL STRUCTURE   METABOLITES  METABOLISM  ANIMAL# RAD        RH-00064
ATION DECONTAMINATION   METAL CHELATES  AMINO ACID ORAL# COM        RH-00042
TOLS  FUNCTIONAL GROUPS METAL COMPLEXES  DISULFIDE BONDS  RE        RH-00297
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..CHROMOSOMES  CYTOLOGY METHODOLOGY  CHROMOSOME ABERRATIONS#        RH-00294
AGING  SEX DIFFERENCE   METHODOLOGY  ENZYMES MECHANISMS RATS        RH-00238
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DOSAGE  INSTRUMENTATION METHODOLOGY RADIATION PROTECTION# RE        RH-00096
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LINICAL STUDY  ANIMAL   METHODOLOGY# AUTOLOGOUS BONE MARROW         RH-00026
OISOTOPES..STRONTIUM 90 METHODOLOGY# EFFECT OF FOOD PROCESSI        RH-00173
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IC SITES..CONNECTICUT    METHODOLOGY# LEVEL OF DENTAL RADIATI      RH-00269
DEOXYURIDINE CATARACT    MICE  ENERGY LEVELS  METABOLISM# RBE      RH-00099
MUTAGENS  ANTIBIOTICS    MICE  MUTATION RATE# ALTERATION OF G      RH-00116
P AMINOPROPRIOPHENONE    MICE HISTOLOGY  TOPICAL APPLICATION       RH-00268
AN IN RADIATION DAMAGED MICE RADIATION EFFECTS  AGE  SEX DIF       RH-00071
RADIATION PROTECTION IN MICE RADIATION PROTECTION  DRUGS  TO       RH-00268
EMIA  SKELETON  AGING    MICE RADIOGRAPHY# AGING AND OTHER SE      RH-00081
ORMALITIES  FERTILITY    MICE..CF1# FETAL X-IRRADIATION, DIFF      RH-00097
HIGH ENERGY ELECTRONS    MICE..SAS/4  HISTOLOGY# THE AGE FACT      RH-00272
OGRAPHY  CYTOGENETICS    MICE# EFFECT OF C-14 ON CYTOGENETICS      RH-00243
CARCINOGENESIS DOSAGE    MICE# EFFECTS OF ZIRCONIUM CITRATE D      RH-00139
Y INFECTIOUS DISEASES    MICE# RADIATION PROTECTION AND RECOV      RH-00239
TIC STRAINS LONGEVITY    MICE# REPAIR RATE AND LIFE SPAN IN R      RH-00071
CELLS BY ALPHA-PARTICLE MICROBEAM ALPHA PARTICLES  MICROBEAM       RH-00002
OBEAM ALPHA PARTICLES    MICROBEAM RADIATION  INSTRUMENTATION      RH-00002
N FALLOUT  SOIL  PLANTS MICROORGANISMS  CHROMATOGRAPHY  ULTR       RH-00124
ION RADIATION EFFECTS    MICROORGANISMS  SLOW ELECTRONS# BIOL      RH-00204
DEOXYRIBONUCLEIC ACID    MICROORGANISMS PHOTOCHEMISTRY  ENZYM      RH-00221
  IONIZATION  PEROXIDES MICROORGANISMS# IMPROVEMENT IN SANIT       RH-00061
ASTS  CHICKENS ELECTRON MICROSCOPY# IRRADIATION OF SINGLE CE       RH-00002
CTS OF RADIATION ON THE MIGRATION OF SALMONIDS# EFFE               RH-00246
OISOTOPES..CESIUM 137    MILK  SOIL RADIOISOTOPES..STRONTIUM       RH-00030
ONTENT OF CESIUM-137 IN MILK RADIATION FALLOUT  RADIOISOTOPE       RH-0003
ADIONUCLIDES IN FLORIDA MILK# R                                    RH-00175
 METAL RADIONUCLIDES BY MINERALS# SORPTION OF HEAVY                RH-00322
IATION DETECTOR PHANTOM MODELS  INSTRUMENTATION METHODOLOGY        RH-00137
GONADS  DOSAGE  PHANTOM MODELS# RADIATION EXPOSURE TO GONADS       RH-00084
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UCLEASES..RIBONUCLEASES MOLECULAR STRUCTURE  CANCER  CHROMAT       RH-00095
ULFIDES A AMINOTHIOLS    MOLECULAR STRUCTURE  FUNCTIONAL GROU      RH-00300
ENATURATION  GAMMA RAYS MOLECULAR STRUCTURE  RADIATION EFFEC       RH-00063
LECULAR ENERGY LEVELS    MOLECULAR STRUCTURE TRIPLET STATE# L      RH-00302
 RAYS  RIBONUCLEIC ACID MOLECULAR WEIGHT  ADENOSINE PHOSPHAT       RH-00089
ION EFFECTS  PROTEINS    MOLECULES..MACROMOLECULES BINDING  I      RH-00005
E WASTES  CRUSTACEANS    MOLLUSKS  MONITORING# RADIOACTIVE AC      RH-00074
ITY IN MARINE ORGANISMS MOLLUSKS  TUNICATES  RADIOACTIVE WAS       RH-00073
S  RADIOACTIVE WASTES    MONITORING  OYSTERS# RADIOACTIVITY I      RH-00073
LOUT  FOOD PROCESSING    MONITORING OCCUPATIONAL HAZARDS  FOO      RH-00173
CRUSTACEANS  MOLLUSKS    MONITORING# RADIOACTIVE ACCUMULATION      RH-00074
ISOTOPES STRONTIUM 90    MONITORING# SR-90 IN DECIDUOUS TEETH      RH-00252
ATED AND NON-IRRADIATED MONKEYS# AGING IN X-RAY IRRADI             RH-00066
ELS  METABOLISM# RBE OF MONOENERGETIC NEUTRONS NEUTRONS  RAD       RH-00099
 DEHYDROGENATION FLAVIN MONONUCLEOTIDES  LUMINESCENCE..BIOLU       RH-00245
NGUE  RADIATION EFFECTS MORBIDITY  AET  CYSTEAMINE  P AMINOP       RH-00268
GENITAL ABNORMALITIES    MORBIDITY MORTALITY  LONGITUDINAL ST      RH-00303
SENSITIVITY  CRITERIA    MORTALITY  HYPOXIA  OVARY OXYGEN TEN      RH-00272
BNORMALITIES  MORBIDITY MORTALITY  LONGITUDINAL STUDY  CHILD       RH-00303
TS SURVEY  PHYSICIANS    MORTALITY  RADIATION HAZARDS  CANCER      RH-00075
IOISOTOPES..COBALT 60    MORTALITY  RADIATION PROTECTION RADI      RH-00257
UDY OF SURVIVORSHIP AND MORTALITY OF RADIOLOGISTS SURVEY  PH       RH-00075
OBULIN VIRUSES..TOBACCO MOSAIC VIRUS  CHROMATOGRAPHY  HUMAN        RH-00063
..STRONTIUM 90  LICHENS MOSS  SOIL  WATER SUPPLY  ECOLOGY..A       RH-00117
ETIC RECORDING SYSTEM    MULTICHANNEL ANALYZER  AGE CLINICAL       RH-00085
 90  CHELATING AGENTS    MUSCLE BONE NEOPLASMS  BONE  RADIOGR      RH-00090
ODY RADIATION  NITROGEN MUSTARDS THYMUS  BLOOD CELLS..LYMPHO       RH-00203
 OF GENETIC REPLICATION MUTAGENS  ANTIBIOTICS  MICE  MUTATIO       RH-00116
NS GENETICS..POLYGENES# MUTATION OF POLYGENES IN DROSOPHILA        RH-00062
NS  ANTIBIOTICS  MICE   MUTATION RATE# ALTERATION OF GENETIC        RH-00116
GENETICS..CHROMOSOMES   MUTATIONS  X RAYS  COLCHICINE URETHA        RH-00143
N EFFECTS  DROSOPHILA   MUTATIONS GENETICS..POLYGENES# MUTAT        RH-00062
CT OF RADIATION-INDUCED MUTATIONS ON FITNESS GENETICS..POPUL        RH-00034
TION  RADIATION EFFECTS NAPHTHALENES  CHLORIDES  IONIZATION         RH-00061
LASMS  THYMUS NEOPLASMS NASOPHARYNX HYPERPLASIA  BURSA  LYMP        RH-00210
      HEIR ENVIRONMENT# NATURAL RADIOACTIVITY IN HUMAN AND I        RH-00316
ING AGENTS  MUSCLE BONE NEOPLASMS  BONE  RADIOGRAPHY  MAMMAL        RH-00090
MBRYO  INFANTS..ANIMALS NEOPLASMS  CATARACT  LEUKEMIA  SKELE        RH-00081
ECTION AND CHEMOTHERAPY NEOPLASMS  RADIATION THERAPY  RADIAT        RH-00026
ATION EFFECTS  X RAYS   NEOPLASMS  THYMUS NEOPLASMS NASOPHAR        RH-00210
 RADIATION PROTECTION   NEOPLASMS  TISSUE HIGH ENERGY ELECTR        RH-00272
ITY  X RAYS  INTESTINAL NEOPLASMS ADENOCARCINOMA  BLOOD FLOW        RH-00221
 RETICULOENDOTHELIOSIS# NEOPLASMS IN CHILDREN TREATED WITH X        RH-00210
SIA  BURSA  LYMPH NODES NEOPLASMS LEUKEMIA  BLOOD DONORS  RA        RH-00210
 BONE MARROW DISEASES   NEOPLASMS LIVER CIRRHOSIS  NERVOUS S        RH-00039
RAYS  NEOPLASMS  THYMUS NEOPLASMS NASOPHARYNX HYPERPLASIA  B        RH-00210
US AUDIOGENIC SEIZURE   NERVE IMPULSE TRANSMISSION  RATS SEN        RH-00306
G  BEHAVIOR  VAGOTOMY   NERVOUS SYSTEM  RATS ADRENAL CORTEX         RH-00068
LASMS LIVER CIRRHOSIS   NERVOUS SYSTEM DISORDERS  LEUKEMIA G        RH-00039
      S# MEASUREMENT OF NEUTRON SPECTRA IN BIOLOGICAL SHIELD        RH-00253
 MONOENERGETIC NEUTRONS NEUTRONS  RADIATION EFFECTS  SPLEEN         RH-00099
M# RBE OF MONOENERGETIC NEUTRONS NEUTRONS  RADIATION EFFECTS        RH-00099
.WHOLE BODY RADIATION   NITROGEN MUSTARDS THYMUS  BLOOD CELL        RH-00213
PERPLASIA  BURSA  LYMPH NODES NEOPLASMS LEUKEMIA  BLOOD DONO        RH-00210
IN X-RAY IRRADIATED AND NON-IRRADIATED MONKEYS# AGING               RH-00066
# PROTEIN METABOLISM IN NORMAL AND IRRADIATED LENSES PROTEIN        RH-00019
  PROTEIN METABOLISM IN NORMAL AND IRRADIATED LENSES#               RH-00345
NUCLEASES..RIBONUCLEASE NUCLEASES..DEOXYRIBONUCLEASE  FLAVON        RH-00218
OTHELIUM PERMEABILITY   NUCLEASES..RIBONUCLEASE NUCLEASES..D        RH-00218
N EFFECTS  GAMMA RAYS   NUCLEASES..RIBONUCLEASES MOLECULAR S        RH-00095
IR OF RADIATION-DAMAGED NUCLEIC ACID ULTRAVIOLET RAYS  DEOXY        RH-00221
D CELL COMPONENTS..CELL NUCLEUS  CELL COMPONENTS..CYTOPLASM         RH-00203
Y# TO STUDY RADIOACTIVE NUCLIDES IN TEETH AND BONE RADIOISOT        RH-00112
IRRHOSIS MALNUTRITION   OBESITY  RADIOLABELED SODIUM  CLINIC        RH-00104
 PROCESSING  MONITORING OCCUPATIONAL HAZARDS  FOOD CONTAMINA        RH-00173
 RADIOAUTOGRAPHY  RATS# OCCUPATIONAL LUNG CANCER FROM IONIZI        RH-00047
S  EYE..LENS  EYE..LENS OPACITY  RADIATION EFFECTS AMINO ACI        RH-00019
AL CHELATES  AMINO ACID ORAL# COMPOUNDS TO PROMOTE EXCRETION        RH-00042
MISTRY PHOTOCHEMISTRY   ORGANIC COMPOUNDS  RADIATION EFFECTS        RH-00332
 FISSION PRODUCT - SOIL ORGANIC MATTER COMPLEXES RADIATION H        RH-00124
RADIOACTIVITY IN MARINE ORGANISMS MOLLUSKS  TUNICATES  RADIO        RH-00073
ICAL RESEARCH ON MARINE ORGANISMS RADIATION EFFECTS  MARINE         RH-00075
UCLIDES ON GRANITE ROCK OUTCROP RADIATION FALLOUT  RADIOISOT        RH-00117
OGENS  TESTIS DISORDERS OVARY  PROSTATE  FERTILITY  RADIOISO        RH-00014
A  MORTALITY  HYPOXIA   OVARY OXYGEN TENSION  RADIATION PROT        RH-00272
ATION  ENZYME SUBSTRATE OXIDASES..LIPOXIDASE  BIOASSAY  RADI        RH-00238
EFFECTS# REDUCED-FLAVIN OXIDATION IN PRIMARY RADIATION DAMAG        RH-00245
  RADIATION SENSITIVITY OXYGEN TENSION  PRIMARY RADIATION EF        RH-00245
RTALITY  HYPOXIA  OVARY OXYGEN TENSION  RADIATION PROTECTION        RH-00272
VE WASTES  MONITORING   OYSTERS# RADIOACTIVITY IN MARINE ORG        RH-00073
RENAL CORTEX HORMONES   PARATHYROID HORMONES CITRATE CHELATI        RH-00222
ARTICLE MICROBEAM ALPHA PARTICLES  MICROBEAM RADIATION  INST        RH-00002
RIBUTION OF RADIOACTIVE PARTICLES IN ENCLOSURES# DIST               RH-00276
ON PROTECTION# REDUCING PATIENT DOSE IN X-RAY DIAGNOSIS X RA        RH-00096
ON EFFECTS AMINO ACID   PEPTIDES  ALBUMINOIDS  RADIOLABELED         RH-00019
Y  RATS..ALBINO  VISUAL PERCEPTION HEART RATE# BEHAVIORAL EF        RH-00065
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 AMINO ACID ENDOTHELIUM PERMEABILITY  NUCLEASES..RIBONUCLEAS         RH-00218
ECTS ON DERMAL VASCULAR PERMEABILITY RADIATION EFFECTS  BETA         RH-00218
CIDS  LIPID PEROXIDES   PEROXIDATION RADIATION EFFECTS..WHOL         RH-00238
ATED FATTY ACIDS  LIPID PEROXIDES  PEROXIDATION RADIATION EF         RH-00238
CHLORIDES  IONIZATION   PEROXIDES MICROORGANISMS# IMPROVEMEN         RH-00061
TECTION  X RAYS  DENTAL PERSONNEL  HARTFORD GEOGRAPHIC SITES         RH-00260
LUMINESCENT DOSIMETRY / PHANTOM AND HUMAN SYSTEMS/ RADIOASSA         RH-00137
ENCE RADIATION DETECTOR PHANTOM MODELS  INSTRUMENTATION METH         RH-00137
UNTERS GONADS  DOSAGE   PHANTOM MODELS# RADIATION EXPOSURE T         RH-00084
ES  GLUTATHIONE GLUCOSE PHOSPHATES  BLOOD CELLS..ERYTHROCYTE         RH-00089
CULAR WEIGHT  ADENOSINE PHOSPHATES  GLUTATHIONE GLUCOSE PHOS         RH-00089
IC ACID  MICROORGANISMS PHOTOCHEMISTRY  ENZYMES  PHOTOREACTI         RH-00221
ATION IN PHOTOCHEMISTRY PHOTOCHEMISTRY  ORGANIC COMPOUNDS  R         RH-00302
ATE# LASER RADIATION IN PHOTOCHEMISTRY PHOTOCHEMISTRY  ORGAN         RH-00302
              OSIMETRY# PHOTOCONDUCTIVE ABSORBED RADIATION D         RH-00159
REACTIVATION  IN VITRO# PHOTOENZYMIC REPAIR OF RADIATION-DAM         RH-00221
OTOCHEMISTRY  ENZYMES   PHOTOREACTIVATION  IN VITRO# PHOTOEN         RH-00221
PHY SPECTROPHOTOMETRY   PHYSICAL CHEMISTRY  INTERFACE# RADIA         RH-00206
TION DRUGS  SYNTHESIS   PHYSICAL CHEMISTRY IMINES# ALPHA-AMI         RH-00300
F RADIOLOGISTS SURVEY   PHYSICIANS  MORTALITY  RADIATION HAZ         RH-00075
X HORMONES  PHYSIOLOGY# PHYSIOLOGICAL BASIS OF RADIATION-CON         RH-00058
CTIVITY  BIOCHEMISTRY   PHYSIOLOGY# LONG-TERM RADIATION EFF          RH-00072
RENAL CORTEX HORMONES   PHYSIOLOGY# PHYSIOLOGICAL BASIS OF R         RH-00068
ADIATION ON HAARSCHEIBE PIGMENT# EFFECTS OF AGING AND R              RH-00163
LOGICAL ACTIVITY GUINEA PIGS  ISOLATION PURIFICATION  REACTI         RH-00257
MINE  SEROTONIN  GUINEA PIGS  RADIOLABELED# BETA-IRRADIATION         RH-00218
S..ERYTHROCYTES  GUINEA PIGS DEHYDROGENASES..PHOSPHOGLUCONAT         RH-00089
EMICAL AGENTS IN GUINEA PIGS RADIATION PROTECTION  X RAYS  R         RH-00089
ACENTRIFUGATION  GUINEA PIGS# POTENTIATION OF ANTIGENS BY GA         RH-00053
AL ANALYSIS OF AGING IN PLANT CELLS AGING  PLANTS  CELL  SEE         RH-00294
 IN PLANT CELLS AGING   PLANTS  CELL  SEEDS  RADIATION SENSI         RH-00294
ATER SUPPLY  ATMOSPHERE PLANTS  ECOLOGY..HUMAN  GEOPHYSICS           RH-00030
DIATION FALLOUT  SOIL   PLANTS MICROORGANISMS  CHROMATOGRAPH         RH-00124
IS  SPECTROPHOTOMETRY   POLAROGRAPHY POTENTIOMETRIC TITRATIO         RH-00124
DIOACTIVE WASTES  WATER POLLUTION ALGAE  FISH  SEASONAL VARI         RH-00077
.POLYGENES# MUTATION OF POLYGENES IN DROSOPHILA BY IRRADIATI         RH-00062
ONUCLEASE  FLAVONOIDS   POLYPEPTIDES HISTAMINE  SEROTONIN  G         RH-00218
             GENESIS OF POSTIRRADIATION HYPERLIPEMIA#                RH-00318
IFUGATION  GUINEA PIGS# POTENTIATION OF ANTIGENS BY GAMMA-IR         RH-00053
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        PROTECTION AGAINST PRENATAL X-IRRADIATION#                   RH-00080
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CED-FLAVIN OXIDATION IN PRIMARY RADIATION DAMAGE IONIZING RA         RH-00245
TIVITY OXYGEN TENSION   PRIMARY RADIATION EFFECTS# REDUCED-F         RH-00245
TES RADIATION EFFECTS   PRIMATES  DRUGS  RADIATION PROTECTIO         RH-00072
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ION EFFECTS ON SUBHUMAN PRIMATES# RADIATION EFFECTS  PRIMATES        RH-00072
ACID ORAL# COMPOUNDS TO PROMOTE EXCRETION OF RADIOISOTOPES R         RH-00042
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SITIVITY  SULFHYDRYLS   PROTEASES..PAPAIN PROTEINS  RADIATIO         RH-00098
TAIN BACTERIA RADIATION PROTECTION  BACTERIA  CARBOHYDRATES          RH-00064
CETAZOLAMIDE  RADIATION PROTECTION  CARCINOGENESIS DOSAGE  M         RH-00139
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YS  CYSTAMINE RADIATION PROTECTION  CYSTEAMINE  AET  MATERNA        RH-00067
SE  BIOASSAY  RADIATION PROTECTION  DIET AGING  SEX DIFFEREN        RH-00238
CTION IN MICE RADIATION PROTECTION  DRUGS  TONGUE  RADIATION        RH-00268
IVITY  X RAYS RADIATION PROTECTION  GENETICS..CHROMOSOMES  C        RH-00294
TOTIC AGENTS  RADIATION PROTECTION  GENETICS..GENES GENETICS        RH-00140
YGEN TENSION  RADIATION PROTECTION  NEOPLASMS  TISSUE HIGH E        RH-00272
DIOPROTECTION RADIATION PROTECTION  RADIATION SENSITIVITY  C        RH-00305
 BASIC THIOLS RADIATION PROTECTION  SYNTHESIS  THIOLS  FUNCT        RH-00297
 IN COMMUNITY RADIATION PROTECTION  X RAYS  DENTAL PERSONNEL        RH-00260
-RAY MACHINES RADIATION PROTECTION  X RAYS  DENTISTRY..ORTHO        RH-00113
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                 ATION# PROTECTION AGAINST PRENATAL X-IRRADI        RH-00080
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TION THERAPY  RADIATION PROTECTION BONE MARROW  BONE MARROW         RH-00026
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LS SYNTHESIS  RADIATION PROTECTION DRUGS  RADIOLABELED REACT        RH-00305
ON MECHANISMS RADIATION PROTECTION DRUGS  SCREENING# RADIOPR        RH-00297
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 APPLICATION  RADIATION PROTECTION DRUGS# LOCAL CHEMICAL RAD        RH-00268
TION EFFECTS  RADIATION PROTECTION HEMATOPOIETIC TISSUES  CH        RH-00239
          RADIATION AND PROTECTION IN ENZYME SYSTEMS#               RH-00197
OCAL CHEMICAL RADIATION PROTECTION IN MICE RADIATION PROTECT        RH-00268
YLOXIMINOMERCAPTANS FOR PROTECTION IN RADIOTHERAPY# ALPHA-AL        RH-00293
O  MORTALITY  RADIATION PROTECTION RADIATION EFFECTS..WHOLE         RH-00257
S  SYNTHESIS  RADIATION PROTECTION RADIATION SENSITIVITY  TH        RH-00193
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L AND IRRADIATED LENSES PROTEINS  EYE..LENS  EYE..LENS OPACI        RH-00019
TES RADIATION EFFECTS   PROTEINS  MOLECULES..MACROMOLECULES         RH-00005
RYLS  PROTEASES..PAPAIN PROTEINS  RADIATION EFFECTS  THIOLS         RH-00098
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 WEIGHT  RATS LOCALIZED RADIATION  CHEMICAL COMPOSITION# REL        RH-00004
ION EFFECTS..WHOLE BODY RADIATION  ENZYME SUBSTRATE OXIDASES        RH-00238
CE PROPERTIES  IONIZING RADIATION  GAS CHROMATOGRAPHY SPECTR        RH-00206
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HA PARTICLES  MICROBEAM RADIATION  INSTRUMENTATION RADIATION        RH-00002
ION EFFECTS..WHOLE BODY RADIATION  NITROGEN MUSTARDS THYMUS         RH-00203
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DIATION DAMAGE IONIZING RADIATION  RADIATION EFFECTS  DEHYDR         RH-00245
NS SANITATION  IONIZING RADIATION  RADIATION EFFECTS NAPHTHA         RH-00061
ION EFFECTS..WHOLE BODY RADIATION  RADIATION FALLOUT BREMSST         RH-00091
ON CHAMBERS  BACKGROUND RADIATION  WATER SAMPLING# BACKGROUN         RH-00054
ION EFFECTS..WHOLE BODY RADIATION  X RAYS  AGE  LUNG RADIATI         RH-00272
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ION PROTECTION# GONADAL RADIATION DURING DERMATOLOGIC X RAY          RH-00258
 RADIATION DAMAGED MICE RADIATION EFFECTS  AGE  SEX DIFFEREN         RH-00071
 AGING OF SMALL ANIMALS RADIATION EFFECTS  AGING  X RAYS  ST         RH-00078
TO BIOLOGICAL MATERIALS RADIATION EFFECTS  AMINO ACID  RADIA         RH-00008
L VASCULAR PERMEABILITY RADIATION EFFECTS  BETA RAYS  SKIN           RH-00219
GE IONIZING RADIATION   RADIATION EFFECTS  DEHYDROGENATION F         RH-00245
OSOPHILA BY IRRADIATION RADIATION EFFECTS  DROSOPHILA  MUTAT         RH-00062
TED EARLY IN FETAL LIFE RADIATION EFFECTS  FETUS  CHILDREN           RH-00207
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S BY IONIZING RADIATION RADIATION EFFECTS  GAMMA RAYS  NUCLE         RH-00095
CHANGES IN MAN X RAYS   RADIATION EFFECTS  GENETICS..CHROMOS         RH-00024
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L WALL  INSTRUMENTATION RADIATION EFFECTS  MICROORGANISMS  S         RH-00204
TS ON SUBHUMAN PRIMATES RADIATION EFFECTS  PRIMATES  DRUGS           RH-00072
N OF PROTEIN AGGREGATES RADIATION EFFECTS  PROTEINS  MOLECUL         RH-00005
ALS GERM FREE  X RAYS   RADIATION EFFECTS  RADIATION PROTECT         RH-00239
HE RAT MATERNAL FETAL   RADIATION EFFECTS  RADIATION PROTECT         RH-00306
ON, AFTER FIFTEEN YEARS RADIATION EFFECTS  RADIOLABELED IRON         RH-00303
TIC NEUTRONS NEUTRONS   RADIATION EFFECTS  SPLEEN  THYMUS  G         RH-00099
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ASES..PAPAIN PROTEINS   RADIATION EFFECTS  THIOLS  DISULFIDE         RH-00098
IATION  INSTRUMENTATION RADIATION EFFECTS  TISSUE CULTURE  F         RH-00002
OID HUMAN CELL CULTURES RADIATION EFFECTS  X RAYS  CELL DIVI         RH-00035
 OF FETAL X-IRRADIATION RADIATION EFFECTS  X RAYS  EMBRYO  I         RH-00081
 IRRADIATION OF THE RAT RADIATION EFFECTS  X RAYS  FETUS  LO         RH-00086
REN TREATED WITH X-RAYS RADIATION EFFECTS  X RAYS  NEOPLASMS         RH-00210
NS  EYE..LENS OPACITY   RADIATION EFFECTS AMINO ACID  PEPTID         RH-00019
TION GENETICS..ANIMAL   RADIATION EFFECTS DROSOPHILA MELANOG         RH-00034
L CHEMISTRY  INTERFACE# RADIATION EFFECTS IN HETEROGENEOUS S         RH-00206
RY  ORGANIC COMPOUNDS   RADIATION EFFECTS LASERS  MOLECULAR          RH-00302
ECTION  DRUGS  TONGUE   RADIATION EFFECTS MORBIDITY  AET  CY         RH-00268
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N  IONIZING RADIATION    RADIATION EFFECTS NAPHTHALENES  CHLO          RH-00061
GEN ANTIBODY REACTIONS# RADIATION EFFECTS ON FORMATION OF PR          RH-00005
  PHYSIOLOGY# LONG-TERM RADIATION EFFECTS ON SUBHUMAN PRIMAT          RH-00072
NTERNATIONAL MEETINGS   RADIATION EFFECTS SECOND INTERNATION          RH-00050
SICS  RADIOASSAY  HUMAN RADIATION EFFECTS..WHOLE BODY RADIAT          RH-00030
POIESIS..ERYTHROPOIESIS RADIATION EFFECTS..WHOLE BODY RADIAT          RH-00186
RADIOACTIVITY IN HUMANS RADIATION EFFECTS..WHOLE BODY RADIAT          RH-00091
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T OF CESIUM-137 IN MILK RADIATION FALLOUT  RADIOISOTOPES..CE          RH-00030
UN GRANITE ROCK OUTCROP RADIATION FALLOUT  RADIOISOTOPES..ST          RH-00117
XES RADIATION HAZARDS   RADIATION FALLOUT  SOIL  PLANTS MICR          RH-00124
.WHOLE BODY RADIATION   RADIATION FALLOUT BREMSSTRAHLUNG COU          RH-00091
URE TEETH  RADIOASSAY   RADIATION FALLOUT RADIOISOTOPES STRO          RH-00252
PHYSICIANS  MORTALITY   RADIATION HAZARDS  CANCER AGE  RADIO          RH-00075
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RGANIC MATTER COMPLEXES RADIATION HAZARDS  RADIATION FALLOUT          RH-00124
DOLOGY# LEVEL OF DENTAL RADIATION HYGIENE IN COMMUNITY RADIA          RH-00260
ER SAMPLING# BACKGROUND RADIATION IN FLORIDA RADIOASSAY  ECO          RH-00054
RE TRIPLET STATE# LASER RADIATION IN PHOTOCHEMISTRY PHOTOCHE          RH-00302
   EFFECTS OF AGING AND RADIATION ON HAARSCHEIBE PIGMENT#             RH-00163
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NCE IN CERTAIN BACTERIA RADIATION PROTECTION  BACTERIA  CARB          RH-00064
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TION  X RAYS  CYSTAMINE RADIATION PROTECTION  CYSTEAMINE  AE          RH-00067
.LIPOXIDASE  BIOASSAY   RADIATION PROTECTION  DIET AGING  SE          RH-00238
TION PROTECTION IN MICE RADIATION PROTECTION  DRUGS  TONGUE           RH-00268
ION SENSITIVITY  X RAYS RADIATION PROTECTION  GENETICS..CHRO          RH-00294
ON ANTIMITOTIC AGENTS   RADIATION PROTECTION  GENETICS..GENE          RH-00140
 OVARY OXYGEN TENSION   RADIATION PROTECTION  NEOPLASMS  TIS          RH-00272
ANGE IN RADIOPROTECTION RADIATION PROTECTION  RADIATION SENS          RH-00305
PROTECTIVE BASIC THIOLS RADIATION PROTECTION  SYNTHESIS  THI          RH-00297
ON HYGIENE IN COMMUNITY RADIATION PROTECTION  X RAYS  DENTAL          RH-00260
N DENTAL X-RAY MACHINES RADIATION PROTECTION  X RAYS  DENTIS          RH-00113
L AGENTS IN GUINEA PIGS RADIATION PROTECTION  X RAYS  RIBONU          RH-00089
ECTIOUS DISEASES  MICE# RADIATION PROTECTION AND RECOVERY IN          RH-00239
ECTS  PRIMATES  DRUGS   RADIATION PROTECTION BEHAVIOR ACTIVI          RH-00072
MS  RADIATION THERAPY   RADIATION PROTECTION BONE MARROW  BO          RH-00026
ASE  THIOLS SYNTHESIS   RADIATION PROTECTION DRUGS  RADIOLAB          RH-00305
DS  REACTION MECHANISMS RADIATION PROTECTION DRUGS  SCREENIN          RH-00297
R CHEMOTHERAPY  THIONES RADIATION PROTECTION DRUGS  SYNTHESI          RH-00300
  TOPICAL APPLICATION   RADIATION PROTECTION DRUGS# LOCAL CH          RH-00268
YS  RADIATION EFFECTS   RADIATION PROTECTION HEMATOPOIETIC T          RH-00239
N DRUGS# LOCAL CHEMICAL RADIATION PROTECTION IN MICE RADIATI          RH-00268
.COBALT 60  MORTALITY   RADIATION PROTECTION RADIATION EFFEC          RH-00257
ES  THIOLS  SYNTHESIS   RADIATION PROTECTION RADIATION SENSI          RH-00193
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AL  RADIATION EFFECTS   RADIATION PROTECTION X RAYS  CYSTEAM        RH-00306
            STUDIES IN RADIATION PROTECTION#                        RH-00321
ADIATION..UNSPECIFIED   RADIATION PROTECTION# GONADAL RADIAT        RH-00258
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IES OF RADIATION DAMAGE RADIATION SENSITIVITY  SULFHYDRYLS          RH-00098
S  RADIATION PROTECTION RADIATION SENSITIVITY  THEORY  REACT        RH-00193
ENTIATION AND FERTILITY RADIATION SENSITIVITY  X RAYS  FETUS        RH-00097
 ON THE SMALL INTESTINE RADIATION SENSITIVITY  X RAYS  INTES        RH-00021
  PLANTS  CELL  SEEDS   RADIATION SENSITIVITY  X RAYS RADIAT        RH-00294
N EFFECTS  AMINO ACID   RADIATION SENSITIVITY CHEMICAL BONDS        RH-00056
TISSUES  CHEMOTHERAPY   RADIATION SENSITIVITY INFECTIOUS DIS        RH-00239
LOGY# THE AGE FACTOR IN RADIATION SENSITIVITY OF MAMMALS RAD        RH-00272
OTOBACTERIUM FISCHERI   RADIATION SENSITIVITY OXYGEN TENSION        RH-00245
HIOL PROTECTION AGAINST RADIATION SULFINAMIDES  THIOLS  SYNT        RH-00193
 X- AND GAMMA RADIATION RADIATION THERAPY  INSTRUMENTATION          RH-00105
HEMOTHERAPY NEOPLASMS   RADIATION THERAPY  RADIATION PROTECT        RH-00026
 X RAY THERAPY GONADS   RADIATION THERAPY  SKIN DISEASES ION        RH-00258
EUKEMIA  BLOOD DONORS   RADIATION THERAPY LONGITUDINAL STUDY        RH-00021
 SKIN DISEASES IONIZING RADIATION..UNSPECIFIED  RADIATION PR        RH-00258
ATION HAZARDS  IONIZING RADIATION..UNSPECIFIED CONDITIONING         RH-00068
 PHYSIOLOGICAL BASIS OF RADIATION-CONDITIONED BEHAVIOR RADIA        RH-00068
 PHOTOENZYMIC REPAIR OF RADIATION-DAMAGED NUCLEIC ACID ULTRA        RH-00221
LOGY..ANIMAL# EFFECT OF RADIATION-INDUCED MUTATIONS ON FITNE        RH-00034
     AMINOTHIOIMIDES AS RADIATION-PROTECTIVE AGENTS#                RH-00324
ES  METABOLISM  ANIMAL# RADIATION-RESISTANCE IN CERTAIN BACT        RH-00064
ION EFFECTS..WHOLE BODY RADIATION# ENVIRONMENTAL EFFECTS ON         RH-0003[illegible]
ECTION AGAINST IONIZING RADIATION# MECHANISM OF PROT                RH-00[illegible]
 SANITATION BY IONIZING RADIATIONS SANITATION  IONIZING RADI        RH-00061
  MOLLUSKS  MONITORING# RADIOACTIVE ACCUMULATION LIMITS IN E        RH-00074
T OF FOOD PROCESSING ON RADIOACTIVE FALLOUT RADIATION FALLOU        RH-00173
S# PRENATAL EXPOSURE TO RADIOACTIVE IRON, AFTER FIFTEEN YEAR        RH-00333
 BONE  SURVEY# TO STUDY RADIOACTIVE NUCLIDES IN TEETH AND BO        RH-00112
        DISTRIBUTION OF RADIOACTIVE PARTICLES IN ENCLOSURES#        RH-00276
ITS IN EDIBLE SHELLFISH RADIOACTIVE WASTES  CRUSTACEANS  MOL        RH-00074
S MOLLUSKS  TUNICATES   RADIOACTIVE WASTES  MONITORING  OYST        RH-00073
H-ORDER DECONTAMINATION RADIOACTIVE WASTES  STRONTIUM  RESIN        RH-00079
RADIOISOTOPES..RADIUM   RADIOACTIVE WASTES  WATER POLLUTION         RH-00077
                        RADIOACTIVITY IN BOTTOM SEDIMENTS#          RH-00369
     IRONMENT# NATURAL RADIOACTIVITY IN HUMAN AND THEIR ENV        RH-00316
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                     M# RADIOACTIVITY IN MAN SECOND SYMPOSIU        RH-00229
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ENTAL STRUCTURE TEETH   RADIOASSAY  RADIATION FALLOUT RADIOI        RH-00252
NTOM AND HUMAN SYSTEMS/ RADIOASSAY  THERMOLUMINESCENCE RADIA        RH-00137
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SION..MITOSIS  GENETICS RADIOAUTOGRAPHY  CYTOGENETICS  MICE#          RH-00243
ISOTOPES..PLUTONIUM 229 RADIOAUTOGRAPHY  RATS# OCCUPATIONAL           RH-00047
GY..ANIMAL  BIOPHYSICS# RADIOBIOLOGICAL RESEARCH ON MARINE O          RH-00076
 ACID HYDROPEROXIDES IN RADIOBIOLOGY UNSATURATED FATTY ACIDS          RH-00238
DENTISTRY..ORTHODONTICS RADIOGRAPHY  CAMERA..PINHOLE# A STUD          RH-00113
 DURING DIAGNOSTIC XRAY RADIOGRAPHY  DIAGNOSTIC..TESTS  SCIN          RH-00084
RAY PROCEDURES X RAYS   RADIOGRAPHY  DOSAGE  FLUOROSCOPY  ST          RH-00085
-RAY DIAGNOSIS X RAYS   RADIOGRAPHY  DOSAGE  INSTRUMENTATION          RH-00096
TUS  LONGITUDINAL STUDY RADIOGRAPHY  GROWTH  CARCINOGENESIS           RH-00086
 BONE NEOPLASMS  BONE   RADIOGRAPHY  MAMMAL  RATS METABOLISM          RH-00090
F X-RAY DOSIMETRIC DATA RADIOGRAPHY  RADIATION COUNTERS  EPI          RH-00092
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ARINE BIOLOGY  X RAYS   RADIOISOTOPES ECOLOGY..ANIMAL  BIOPH          RH-00076
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DIOISOTOPES..CESIUM 137 RADIOISOTOPES..CESIUM 134  METHODOLO          RH-00091
ILK RADIATION FALLOUT   RADIOISOTOPES..CESIUM 137  MILK  SOI          RH-0003
DIOISOTOPES..IODINE 131 RADIOISOTOPES..CESIUM 137  RADIOISOT          RH-00173
OISOTOPES..STRONTIUM 90 RADIOISOTOPES..CESIUM 137  STREAMS            RH-00215
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CTIVE FACTOR IN ALFALFA RADIOISOTOPES..COBALT 60  MORTALITY           RH-00257
  GENETICS..CHROMOSOMES RADIOISOTOPES..COBALT 60  SKIN  BLOO          RH-00024
DIOISOTOPES..SILICON 31 RADIOISOTOPES..COPPER 64  RADIOISOTO          RH-00215
ATION DECONTAMINATION   RADIOISOTOPES..IODINE 131 RADIOISOTO          RH-00173
WATERS  ECOLOGY..ANIMAL RADIOISOTOPES..PHOSPHORUS 32  RADIOI          RH-00215
SOTOPES..THALLIUM 204   RADIOISOTOPES..PHOSPHORUS 32 RADIOIS          RH-00047
OISOTOPES..YTTRIUM 90   RADIOISOTOPES..PLUTONIUM 229 RADIOAU          RH-00047
OTA BELOW URANIUM MILLS RADIOISOTOPES..RADIUM  RADIOACTIVE W          RH-00077
ISOTOPES..RUTHENIUM 106 RADIOISOTOPES..RHODIUM 106  RADIOISO          RH-00047
INOMA LUNG..NEOPLASMS   RADIOISOTOPES..RUTHENIUM 106 RADIOIS          RH-00047
OTOPES..PHOSPHORUS 32   RADIOISOTOPES..SILICON 31 RADIOISOTO          RH-00215
LISM AND REMOVAL IN MAN RADIOISOTOPES..STRONTIUM 85  MAGNESI          RH-00222
TRATE  CHELATING AGENTS RADIOISOTOPES..STRONTIUM 89  RADIOIS          RH-00139
EMSSTRAHLUNG COUNTERS   RADIOISOTOPES..STRONTIUM 90  BONE RA          RH-00091
IOSTRONTIUM ELIMINATION RADIOISOTOPES..STRONTIUM 90  CHELATI          RH-00090
LIDES IN TEETH AND BONE RADIOISOTOPES..STRONTIUM 90  DENTAL           RH-00112
ROP RADIATION FALLOUT   RADIOISOTOPES..STRONTIUM 90  LICHENS          RH-00117
.CESIUM 137  MILK  SOIL RADIOISOTOPES..STRONTIUM 90  WATER S          RH-0003
SOTOPES..STRONTIUM 89   RADIOISOTOPES..STRONTIUM 90 ACETAZOL          RH-00139
OISOTOPES..CESIUM 137   RADIOISOTOPES..STRONTIUM 90 METHODOL          RH-00173
IOISOTOPES..COPPER 64   RADIOISOTOPES..STRONTIUM 90 RADIOISO          RH-00215
ISOTOPES..RHODIUM 106   RADIOISOTOPES..TECHNETIUM 99 RADIOIS          RH-00047
ISOTOPES..TECHNETIUM 99 RADIOISOTOPES..THALLIUM 204  RADIOIS          RH-00047
ISOTOPES..PHOSPHORUS 32 RADIOISOTOPES..YTTRIUM 90  RADIOISOT          RH-00047
  PROSTATE  FERTILITY   RADIOISOTOPES..ZINC 65# BIOCHEMICAL           RH-00014
PEPTIDES  ALBUMINOIDS   RADIOLABELED  RATS METABOLISM# PROTE          RH-00019
 RADIOLABELED TRITIUM   RADIOLABELED BROMINE# BODY COMPOSITI          RH-00104
PES..STRONTIUM 90  BONE RADIOLABELED CALCIUM  RADIOLABELED C          RH-00091
RADIOLABELED IRON  CARP RADIOLABELED CARBON# RADIOSENSITIVIT          RH-00186
 RADIOLABELED CALCIUM   RADIOLABELED COBALT RADIOLABELED STR          RH-00091
D CELLS..ERYTHROCYTES   RADIOLABELED IRON  CARP RADIOLABELED          RH-00186
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ARS RADIATION EFFECTS   RADIOLABELED IRON  MATERNAL FETAL CA       RH-00304
TION PROTECTION DRUGS   RADIOLABELED REACTION MECHANISMS  2        RH-00405
MALNUTRITION  OBESITY   RADIOLABELED SODIUM  CLINICAL STUDY        RH-00104
UM  RADIOLABELED COBALT RADIOLABELED STRONTIUM  RADIOISOTOPE       RH-00091
 SODIUM  CLINICAL STUDY RADIOLABELED TRITIUM  RADIOLABELED B       RH-00104
EROTONIN  GUINEA PIGS   RADIOLABELED# BETA-IRRADIATION EFFEC       RH-00218
COMPUTING TECHNIQUES IN RADIOLOGICAL PROBLEMS# DIGITAL             RH-00286
ORSHIP AND MORTALITY OF RADIOLOGISTS SURVEY  PHYSICIANS  MOR       RH-00075
N HAZARDS  CANCER AGE   RADIOLOGISTS# A STUDY OF SURVIVORSHI       RH-00075
S CANCER CHEMOTHERAPY   RADIOMIMETIC AGENTS  CLINICAL STUDY#       RH-00024
TS# EFFECT OF X-RAY AND RADIOMIMETIC AGENTS ON LYMPHOCYTES R       RH-00203
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 /ENRICHMENT/ CHAINS OF RADIONUCLIDES IN FINNISH LAKES# BIOL       RH-00307
                        RADIONUCLIDES IN FLORIDA MILK#             RH-00175
LOID-SOLUTE SORBTION OF RADIONUCLIDES IN WATER# COL                RH-00183
MAL# BIOACCUMULATION OF RADIONUCLIDES ON GRANITE ROCK OUTCRO       RH-00117
ISULFIDE INTERCHANGE IN RADIOPROTECTION RADIATION PROTECTION       RH-00305
CTION DRUGS  SCREENING* RADIOPROTECTIVE BASIC THIOLS RADIATI       RH-00297
TE# CHARACTERIZATION OF RADIOPROTECTIVE FACTOR IN ALFALFA RA       RH-00257
CELL DIVISION CYCLE AND RADIOSENSITIVITY - METABOLIC STUDIES       RH-00304
GICAL FACTORS AFFECTING RADIOSENSITIVITY IN YEAST# BIOLO           RH-00312
RP RADIOLABELED CARBON# RADIOSENSITIVITY OF EXTRAMEDULLAR ER       RH-00186
 OF CHELATING AGENTS ON RADIOSTRONTIUM ELIMINATION RADIOISOT       RH-00090
NICAL STUDY# STUDIES OF RADIOSTRONTIUM METABOLISM AND REMOVA       RH-00227
PTANS FOR PROTECTION IN RADIOTHERAPY# ALPHA-ALKYLOXIMINOMERC       RH-00293
L VARIATION# EFFECTS OF RADIUM ON STREAM BIOTA BELOW URANIUM       RH-00077
ION OF THE EXTERIORIZED RAT KIDNEY# EFFECTS OF IRRADIAT            RH-00316
ATALLY, BEHAVIOR OF THE RAT MATERNAL FETAL  RADIATION EFFECT       RH-00306
TERO IRRADIATION OF THE RAT RADIATION EFFECTS  X RAYS  FETUS       RH-00086
NCE  DOSAGE  METASTASIS RATS  HISTOCOMPATIBILITY# EFFECTS OF       RH-00021
OTOMY  NERVOUS SYSTEM   RATS ADRENAL CORTEX HORMONES  PHYSIO       RH-00068
 DENSITY  BONE WEIGHT   RATS LOCALIZED RADIATION  CHEMICAL C       RH-00004
  RADIOGRAPHY  MAMMAL   RATS METABOLISM# EFFECTS OF CHELATIN       RH-00090
MINOIDS  RADIOLABELED   RATS METABOLISM# PROTEIN METABOLISM        RH-00019
EARNING IN X-IRRADIATED RATS RADIATION EFFECTS..WHOLE BODY R       RH-00057
 IMPULSE TRANSMISSION   RATS SENSORY DISORDERS  ADRENAL GLAN       RH-00[illegible]
CS LONGITUDINAL STUDY   RATS..ALBINO  VISUAL PERCEPTION HEAR       RH-00055
ROWTH  CARCINOGENESIS   RATS..ALBINO CONGENITAL ABNORMALITIE       RH-00086
  PSYCHOLOGICAL TESTS   RATS# AET AND DISCRIMINATION LEARNIN       RH-00057
LYTES  ENZYMES  BRAIN   RATS# EFFECTS OF IRRADIATION ON AGIN       RH-00078
UGY  ENZYMES MECHANISMS RATS# FATTY ACID HYDROPEROXIDES IN R       RH-00238
M 229 RADIOAUTOGRAPHY   RATS# OCCUPATIONAL LUNG CANCER FROM        RH-00047
N DURING DERMATOLOGIC X RAY THERAPY GONADS  RADIATION THERAP       RH-00258
WHOLE BODY RADIATION  X RAYS  AGE  LUNG RADIATION SENSITIVI        RH-00272
WHOLE BODY RADIATION  X RAYS  AGE SKELETON  GROWTH  BONE DEN       RH-00004
ES RADIATION EFFECTS  X RAYS  CELL DIVISION..MITOSIS KB CELL       RH-00035
ROMOSOMES  MUTATIONS  X RAYS  COLCHICINE URETHAN  8 AZAGUANI       RH-00145
WHOLE BODY RADIATION  X RAYS  CYSTAMINE RADIATION PROTECTION       RH-00367
 RADIATION PROTECTION X RAYS  CYSTEAMINE  BEHAVIOR  MENTAL R       RH-00316
RADIATION PROTECTION  X RAYS  DENTAL PERSONNEL  HARTFORD GEO       RH-00263
RADIATION PROTECTION  X RAYS  DENTISTRY..ORTHODONTICS RADIOG       RH-00111
UCLEIC ACID ULTRAVIOLET RAYS  DEOXYRIBONUCLEIC ACID  MICROOR       RH-00224
EFFECTS  FLUOROSCOPY  X RAYS  DOSAGE ELECTRONIC RECORDING  I       RH-00033
ON RADIATION EFFECTS  X RAYS  EMBRYO  INFANTS..ANIMALS NEOPL       RH-00061
ADIATION SENSITIVITY  X RAYS  FETUS  AGE  SEX DIFFERENCE CON       RH-00097
AT RADIATION EFFECTS  X RAYS  FETUS  LONGITUDINAL STUDY RADI       RH-00086
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ADIATION SENSITIVITY  X RAYS  INTESTINAL NEOPLASMS ADENOCARC    RH-00021
YS RADIATION EFFECTS  X RAYS  NEOPLASMS  THYMUS NEOPLASMS NA    RH-00210
ADIATION EFFECTS  GAMMA RAYS  NUCLEASES..RIBONUCLEASES MOLEC    RH-00095
MOSOME CHANGES IN MAN X RAYS  RADIATION EFFECTS  GENETICS..C    RH-00024
EE ANIMALS GERM FREE  X RAYS  RADIATION EFFECTS  RADIATION P    RH-00239
STIC X-RAY PROCEDURES X RAYS  RADIOGRAPHY  DOSAGE  FLUOROSCO    RH-00085
SE IN X-RAY DIAGNOSIS X RAYS  RADIOGRAPHY  DOSAGE  INSTRUMEN    RH-00096
ECTS  MARINE BIOLOGY  X RAYS  RADIOISOTOPES ECOLOGY..ANIMAL     RH-00076
RADIATION PROTECTION  X RAYS  RIBONUCLEIC ACID MOLECULAR WEI    RH-00089
RADIATION EFFECTS  BETA RAYS  SKIN  BRADYKININ  AMINO ACID E    RH-00218
ATION EFFECTS  AGING  X RAYS  STRESS  ANGIOTENSIN ELECTROLYT    RH-00078
ELECTRODES  ULTRAVIOLET RAYS  X RAYS SURFACE PROPERTIES  ION    RH-00206
NTATION  CALORIMETRY  X RAYS GAMMA RAYS# CALORIMETRIC MEASUR    RH-00165
INS DENATURATION  GAMMA RAYS MOLECULAR STRUCTURE  RADIATION     RH-00063
ADIATION SENSITIVITY  X RAYS RADIATION PROTECTION  GENETICS.    RH-00294
ES  ULTRAVIOLET RAYS  X RAYS SURFACE PROPERTIES  IONIZING RA    RH-00206
LORIMETRY  X RAYS GAMMA RAYS# CALORIMETRIC MEASUREMENTS OF X    RH-00165
RGY LEVELS  METABOLISM# RBE OF MONOENERGETIC NEUTRONS NEUTRO    RH-00099
               TED CELLS# REACTIVE LIFETIME STUDIES IN IRRADIA  RH-00340
ADIATION PROTECTION AND RECOVERY IN GERMFREE ANIMALS GERM FR    RH-00239
MARY RADIATION EFFECTS# REDUCED-FLAVIN OXIDATION IN PRIMARY     RH-00245
HEMICAL MODIFICATION OF REGIONAL RADIATION REACTION# C          RH-00224
TRONTIUM METABOLISM AND REMOVAL IN MAN RADIOISOTOPES..STRONT    RH-00222
 IN VITRO# PHOTOENZYMIC REPAIR OF RADIATION-DAMAGED NUCLEIC     RH-00221
TRAINS LONGEVITY  MICE# REPAIR RATE AND LIFE SPAN IN RADIATI    RH-00071
# ALTERATION OF GENETIC REPLICATION MUTAGENS  ANTIBIOTICS  M    RH-00116
IVE WASTES  STRONTIUM   RESINS..ION EXCHANGE WASTE TREATMENT    RH-00079
           DIFFERENTIAL RESISTANCE OF CELLS TO IRRADIATION#     RH-00325
PERATURE  ELECTRON SPIN RESONANCE SPECTROSCOPY# ENZYMATIC AN    RH-00098
 CLEAVAGE ELECTRON SPIN RESONANCE SPECTROSCOPY# STUDIES OF R    RH-00098
AMINE  BEHAVIOR  MENTAL RETARDATION  FETUS AUDIOGENIC SEIZUR    RH-00306
 BLOOD..PLASMA  CALCIUM RETENTION  METABOLISM  CLINICAL STUD    RH-00222
..CESIUM 137  STREAMS   RETENTION  TUBIFEX# ACCUMULATION AND    RH-00215
SIUM 134  METHODOLOGY   RETENTION METABOLISM# WHOLE-BODY COU    RH-00091
BIFEX# ACCUMULATION AND RETENTION OF RADIONUCLIDES BY TUBIFE    RH-00215
  EFFECT OF FLUORIDE ON RETENTION OF SR90#                      RH-00114
URVEY  CHILDREN  ADULTS RETICULOENDOTHELIOSIS# NEOPLASMS IN     RH-00210
LYMPHOCYTES  AMINO ACID RIBONUCLEIC ACID  DEOXYRIBONUCLEIC A    RH-00203
ON PROTECTION  X RAYS   RIBONUCLEIC ACID MOLECULAR WEIGHT  A    RH-00089
ADIONUCLIDES ON GRANITE ROCK OUTCROP RADIATION FALLOUT  RADI    RH-00117
ION ON THE MIGRATION OF SALMONIDS# EFFECTS OF RADIAT            RH-00246
 BY IONIZING RADIATIONS SANITATION  IONIZING RADIATION  RADI    RH-00061
GANISMS# IMPROVEMENT IN SANITATION BY IONIZING RADIATIONS SA    RH-00061
      CHROMOSOMES AFTER SCALP X-RAYS AND IN GENODERMATOSES#     RH-00299
L INFORMATION FROM BODY SCANNING CONFERENCES  BIOPHYSICS  RA    RH-00032
L INFORMATION FROM BODY SCANNING# EXTRACTION OF MAXIMAL INFO    RH-00032
HY  DIAGNOSTIC..TESTS   SCINTILLATION COUNTERS GONADS  DOSAG    RH-00084
SOTOPES  AIR SAMPLING   SCINTILLATION COUNTERS IONIZATION CH    RH-00054
TION PROTECTION DRUGS   SCREENING# RADIOPROTECTIVE BASIC THI    RH-00297
POLLUTION ALGAE  FISH   SEASONAL VARIATION# EFFECTS OF RADIU    RH-00077
RADIOACTIVITY IN BOTTOM SEDIMENTS#                              RH-00369
S AGING  PLANTS  CELL   SEEDS  RADIATION SENSITIVITY  X RAYS    RH-00294
ATION  FETUS AUDIOGENIC SEIZURE  NERVE IMPULSE TRANSMISSION     RH-00306
ULSE TRANSMISSION  RATS SENSORY DISORDERS  ADRENAL GLANDS  A    RH-00306
GRAPHY# AGING AND OTHER SEQUELAE OF FETAL X-IRRADIATION RADI    RH-00081
ARROW  CHIMERAS  TYPING SERA  CHEMOTHERAPY  PRIMATES MALABSO    RH-00311
S SUBSTRATE  CYSTEAMINE SEROTININ  HISTAMINE  ZONE ELECTROPH    RH-00203
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OLYPEPTIDES HISTAMINE	SEROTONIN GUINEA PIGS RADIOLABELED	RH-00218
ADIATION EFFECTS AGE	SEX DIFFERENCE GENETIC STRAINS LONG	RH-00071
ROTECTION DIET AGING	SEX DIFFERENCE METHODOLOGY ENZYMES	RH-00238
Y X RAYS FETUS AGE	SEX DIFFERENCE CONGENITAL ABNORMALIT	RH-00097
LATION LIMITS IN EDIBLE	SHELLFISH RADIOACTIVE WASTES CRUSTA	RH-00074
N SPECTRA IN BIOLOGICAL	SHIELDS# MEASUREMENT OF NEUTRO	RH-00253
ROSCOPY# IRRADIATION OF	SINGLE CELLS BY ALPHA-PARTICLE MICRO	RH-00002
EL HARTFORD GEOGRAPHIC	SITES..CONNECTICUT METHODOLOGY# LEV	RH-00260
AMINATION GEOGRAPHICAL	SITES..FLORIDA RADIOISOTOPES AIR SA	RH-00054
ION# RELATION OF AGE TO	SKELETAL EFFECTS OF X-RADIATION RADI	RH-00004
S CATARACT LEUKEMIA	SKELETON AGING MICE RADIOGRAPHY# A	RH-00081
RADIATION X RAYS AGE	SKELETON GROWTH BONE DENSITY BONE	RH-00004
IOISOTOPES..COBALT 60	SKIN BLOOD CELLS CANCER CHEMOTHERAP	RH-00024
ON EFFECTS BETA RAYS	SKIN BRADYKININ AMINO ACID ENDOTHE	RH-00218
DS RADIATION THERAPY	SKIN DISEASES IONIZING RADIATION..UN	RH-00258
FECTS MICROORGANISMS	SLOW ELECTRONS# BIOLOGICAL EFFECTS O	RH-00204
OBESITY RADIOLABELED	SODIUM CLINICAL STUDY RADIOLABELED	RH-00104
RONTIUM 85 MAGNESIUM	SODIUM SULFATE ADRENAL CORTEX HORMON	RH-00222
DS RADIATION FALLOUT	SOIL PLANTS MICROORGANISMS CHROMAT	RH-00124
TIUM 90 LICHENS MOSS	SOIL WATER SUPPLY ECOLOGY..ANIMAL#	RH-00117
OSPHERE WATER SUPPLY	SOIL FOOD CONTAMINATION GEOGRAPHICA	RH-00054
ONS# FISSION PRODUCT -	SOIL ORGANIC MATTER COMPLEXES RADIAT	RH-00124
PES..CESIUM 137 MILK	SOIL RADIOISOTOPES..STRONTIUM 90 WA	RH-00030
RUMENTATION METHODOLOGY	SOLID STATE..CHEMISTRY CLINICAL STU	RH-00137
NS..CHEMISTRY COLLOIDS	SOLUTIONS ELECTRODES ULTRAVIOLET R	RH-00206
COLLOID-SOLUTE	SORBTION OF RADIONUCLIDES IN WATER#	RH-00183
S BY MINERALS#	SORPTION OF HEAVY METAL RADIONUCLIDE	RH-00327
E# REPAIR RATE AND LIFE	SPAN IN RADIATION DAMAGED MICE RADIA	RH-00071
MEASUREMENT OF NEUTRON	SPECTRA IN BIOLOGICAL SHIELDS#	RH-00253
OMATOGRAPHY ULTRAVIOLET	SPECTROMETRY# INACTIVATIONS OF ENZYM	RH-00095
ION GAS CHROMATOGRAPHY	SPECTROPHOTOMETRY PHYSICAL CHEMISTR	RH-00206
ATION ELECTROPHORESIS	SPECTROPHOTOMETRY POLAROGRAPHY POTE	RH-00124
ELECTRON SPIN RESONANCE	SPECTROSCOPY# ENZYMATIC AND ESR STUD	RH-00098
ELECTRON SPIN RESONANCE	SPECTROSCOPY# STUDIES OF RADIATION D	RH-00008
INE 6 MERCAPTOPURINE	SPERMATOGENESIS DROSOPHILA MELANOGAS	RH-00140
S TEMPERATURE ELECTRON	SPIN RESONANCE SPECTROSCOPY# ENZYMAT	RH-00098
.BOND CLEAVAGE ELECTRON	SPIN RESONANCE SPECTROSCOPY# STUDIES	RH-00008
NS RADIATION EFFECTS	SPLEEN THYMUS GERM CELLS THYMIDINE	RH-00099
ION RADIATION EFFECTS	SQUAMOUS CELL CARCINOMA LUNG..NEOPLA	RH-00047
OF ZIRCONIUM CITRATE ON	SR-89 BONE CANCER BONE..NEOPLASMS Z	RH-00139
RONTIUM 90 MONITORING#	SR-90 IN DECIDUOUS TEETH IN THE GULF	RH-00252
SM STUDIES OF I-131 AND	SR-90# ALTERED METABOLI	RH-00211
LUORIDE ON RETENTION OF	SR90# EFFECT OF F	RH-00114
ATION METHODOLOGY SOLID	STATE..CHEMISTRY CLINICAL STUDY# TH	RH-00137
CULAR STRUCTURE TRIPLET	STATE# LASER RADIATION IN PHOTOCHEMI	RH-00302
COMPOSITION IN DISEASE	STATES BODY COMPOSITION HYPERTENSIO	RH-00104
DOSAGE FLUOROSCOPY	STATISTICS MAGNETIC RECORDING SYSTEM	RH-00085
S EPIDEMIOLOGY DOSAGE	STATISTICS# EPIDEMIOLOGICAL APPLICAT	RH-00092
ION RADIATION EFFECTS	STEROIDS ANDROGENS TESTIS DISORDER	RH-00014
SEX DIFFERENCE GENETIC	STRAINS LONGEVITY MICE# REPAIR RATE	RH-00071
N# EFFECTS OF RADIUM ON	STREAM BIOTA BELOW URANIUM MILLS RAD	RH-00077
OISOTOPES..CESIUM 137	STREAMS RETENTION TUBIFEX# ACCUMUL	RH-00215
FFECTS AGING X RAYS	STRESS ANGIOTENSIN ELECTROLYTES EN	RH-00078
LED COBALT RADIOLABELED	STRONTIUM RADIOISOTOPES..CESIUM 137	RH-00091
ON RADIOACTIVE WASTES	STRONTIUM RESINS..ION EXCHANGE WAST	RH-00079
N FALLOUT RADIOISOTOPES	STRONTIUM 90 MONITORING# SR-90 IN D	RH-00252
ELOPING TEETH#	STRONTIUM 90 EFFECTS ON PULP AND DEV	RH-00343

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RIBONUCLEASES MOLECULAR STRUCTURE  CANCER  CHROMATOGRAPHY UL        RH-00095
 AMINOTHIOLS  MOLECULAR STRUCTURE  FUNCTIONAL GROUPS SYNTHES        RH-00300
ATES  EXTRACTS CHEMICAL STRUCTURE  METABOLITES  METABOLISM          RH-00064
N  GAMMA RAYS MOLECULAR STRUCTURE  RADIATION EFFECTS  HEMOCY        RH-00063
TS  HEMOCYANIN CHEMICAL STRUCTURE BIOLOGICAL ACTIVITY  GAMMA        RH-00063
UPS SYNTHESIS  CHEMICAL STRUCTURE BIOLOGICAL ACTIVITY A AMIN        RH-00300
FRACTIONATION  CHEMICAL STRUCTURE BIOLOGICAL ACTIVITY GUINEA        RH-00257
 GULF COAST AREA DENTAL STRUCTURE TEETH  RADIOASSAY  RADIATI        RH-00252
NERGY LEVELS  MOLECULAR STRUCTURE TRIPLET STATE# LASER RADIA        RH-00302
S..STRONTIUM 90  DENTAL STRUCTURE..TEETH CHILDREN  BONE  SUR        RH-00112
RM RADIATION EFFECTS ON SUBHUMAN PRIMATES RADIATION EFFECTS         RH-00072
TS..MICROSOMES  ENZYMES SUBSTRATE  CYSTEAMINE SEROTININ  HIS        RH-00203
 BODY RADIATION  ENZYME SUBSTRATE OXIDASES..LIPOXIDASE  BIOA        RH-00238
CHANGE CHROMATOGRAPHY   SUBSTRATE# CHARACTERIZATION OF RADIO        RH-00257
M 85  MAGNESIUM  SODIUM SULFATE ADRENAL CORTEX HORMONES  PAR        RH-00222
RADIATION SENSITIVITY   SULFHYDRYLS  PROTEASES..PAPAIN PROTE        RH-00098
OGICAL ACTIVITY A AMINO SULFIDES  BIOASSAY  CANCER CHEMOTHER        RH-00300
CAPTANS AND ALPHA-AMINO SULFIDES A AMINOTHIOLS  MOLECULAR ST        RH-00300
CTION AGAINST RADIATION SULFINAMIDES  THIOLS  SYNTHESIS  RAD        RH-00193
ES..STRONTIUM 90  WATER SUPPLY  ATMOSPHERE PLANTS  ECOLOGY..        RH-00030
CHENS MOSS  SOIL  WATER SUPPLY  ECOLOGY..ANIMAL# BIOACCUMULA        RH-00117
UMAN  ATMOSPHERE  WATER SUPPLY  SOIL FOOD CONTAMINATION  GEO        RH-00054
LTRAVIOLET RAYS  X RAYS SURFACE PROPERTIES  IONIZING RADIATI        RH-00206
PY LONGITUDINAL STUDY   SURVEY  CHILDREN  ADULTS RETICULOEND        RH-00210
RTALITY OF RADIOLOGISTS SURVEY  PHYSICIANS  MORTALITY  RADIA        RH-00075
.TEETH CHILDREN  BONE   SURVEY# TO STUDY RADIOACTIVE NUCLIDE        RH-00112
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OACTIVITY IN MAN SECOND SYMPOSIUM# RADI                             RH-00229
 PRIMATES MALABSORPTION SYNDROMES  METABOLISM  DOGS# IRRADIA        RH-00311
TURE  FUNCTIONAL GROUPS SYNTHESIS  CHEMICAL STRUCTURE BIOLOG        RH-00300
TION PROTECTION DRUGS   SYNTHESIS  PHYSICAL CHEMISTRY IMINES        RH-00300
L DEHYDROGENASE  THIOLS SYNTHESIS  RADIATION PROTECTION DRUG        RH-00305
 SULFINAMIDES  THIOLS   SYNTHESIS  RADIATION PROTECTION RADI        RH-00193
 RADIATION PROTECTION   SYNTHESIS  THIOLS  FUNCTIONAL GROUPS        RH-00297
TICS MAGNETIC RECORDING SYSTEM  MULTICHANNEL ANALYZER  AGE C        RH-00085
VIOR  VAGOTOMY  NERVOUS SYSTEM  RATS ADRENAL CORTEX HORMONES        RH-00068
IVER CIRRHOSIS  NERVOUS SYSTEM DISORDERS  LEUKEMIA GRANULOMA        RH-00039
AL STUDIES ON ENDOCRINE SYSTEM UNDER RADIATION RADIATION EFF        RH-00014
FFECTS IN HETEROGENEOUS SYSTEMS RADIATION EFFECTS  SUSPENSIO        RH-00206
ETRY /PHANTOM AND HUMAN SYSTEMS/ RADIOASSAY  THERMOLUMINESCE        RH-00137
ND PROTECTION IN ENZYME SYSTEMS# RADIATION A                        RH-00197
T AREA DENTAL STRUCTURE TEETH  RADIOASSAY  RADIATION FALLOUT        RH-00252
RADIOACTIVE NUCLIDES IN TEETH AND BONE RADIOISOTOPES..STRONT        RH-00112
ING# SR-90 IN DECIDUOUS TEETH IN THE GULF COAST AREA DENTAL         RH-00252
 ON PULP AND DEVELOPING TEETH# STRONTIUM 90 EFFECTS                 RH-00343
CTS  THIOLS  DISULFIDES TEMPERATURE  ELECTRON SPIN RESONANCE        RH-00098
TION SENSITIVITY OXYGEN TENSION  PRIMARY RADIATION EFFECTS#         RH-00245
  HYPOXIA  OVARY OXYGEN TENSION  RADIATION PROTECTION  NEOPL        RH-00272
  STEROIDS  ANDROGENS   TESTIS DISORDERS OVARY  PROSTATE  FE        RH-00014
MMA RADIATION RADIATION THERAPY  INSTRUMENTATION  CALORIMETR        RH-00105
PY NEOPLASMS  RADIATION THERAPY  RADIATION PROTECTION BONE M        RH-00026
ERAPY GONADS  RADIATION THERAPY  SKIN DISEASES IONIZING RADI        RH-00258
RING DERMATOLOGIC X RAY THERAPY GONADS  RADIATION THERAPY  S        RH-00258
BLOOD DONORS  RADIATION THERAPY LONGITUDINAL STUDY  SURVEY          RH-00210
DOSIMETRY FOR COBALT-60 THERAPY# CLINICAL                           RH-00045
N SYSTEMS/ RADIOASSAY   THERMOLUMINESCENCE RADIATION DETECTO        RH-00137
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ECHANISMS# MECHANISM OF THIOL PROTECTION AGAINST RADIATION S          RH-00193
NS  RADIATION EFFECTS   THIOLS  DISULFIDES TEMPERATURE  ELEC          RH-00098
PROTECTION  SYNTHESIS   THIOLS  FUNCTIONAL GROUPS METAL COMP          RH-00297
ADIATION SULFINAMIDES   THIOLS  SYNTHESIS  RADIATION PROTECT          RH-00193
# RADIOPROTECTIVE BASIC THIOLS RADIATION PROTECTION  SYNTHES          RH-00297
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  CANCER CHEMOTHERAPY   THIONES RADIATION PROTECTION DRUGS            RH-00303
HE EFFECT OF THOROTRAST THOROTRAST  BIOMETRY  BONE MARROW DI          RH-00039
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TION  NITROGEN MUSTARDS THYMUS  BLOOD CELLS..LYMPHOCYTES  AM          RH-00213
ATION EFFECTS  SPLEEN   THYMUS  GERM CELLS THYMIDINE  TRITIU          RH-00099
TS  X RAYS  NEOPLASMS   THYMUS NEOPLASMS NASOPHARYNX HYPERPL          RH-00210
-UP STUDY OF IRRADIATED TINEA CAPITIS CASES# FOLLOW                   RH-00298
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ROTECTION HEMATOPOIETIC TISSUES  CHEMOTHERAPY  RADIATION SEN          RH-00259
ROGRAPHY POTENTIOMETRIC TITRATIONS# FISSION PRODUCT - SOIL O          RH-00124
ION PROTECTION  DRUGS   TONGUE  RADIATION EFFECTS MORBIDITY           RH-00268
ENONE  MICE HISTOLOGY   TOPICAL APPLICATION  RADIATION PROTE          RH-00268
E BODY RADIATION  BLOOD TRANSFUSION BONE MARROW  CHIMERAS  T          RH-00311
 SEIZURE  NERVE IMPULSE TRANSMISSION  RATS SENSORY DISORDERS          RH-00336
 IRRADIATION AND MARROW TRANSPLANTATION IN LARGE ANIMALS IMM          RH-00311
EN ANTIBODY REACTIONS   TRANSPLANTATION RADIATION EFFECTS..M          RH-00311
LS  MOLECULAR STRUCTURE TRIPLET STATE# LASER RADIATION IN PH          RH-00307
 GERM CELLS THYMIDINE   TRITIUM  BONE MARROW  5 IODODEOXYURI          RH-0009
ICAL STUDY RADIOLABELED TRITIUM  RADIOLABELED BROMINE# BODY           RH-00104
ION OF RADIONUCLIDES BY TUBIFEX RADIATION HAZARDS  INLAND FR          RH-00215
7  STREAMS  RETENTION   TUBIFEX# ACCUMULATION AND RETENTION           RH-00215
NE ORGANISMS MOLLUSKS   TUNICATES  RADIOACTIVE WASTES  MONIT          RH-00073
BONE MARROW  CHIMERAS   TYPING SERA  CHEMOTHERAPY  PRIMATES           RH-00311
NISMS  CHROMATOGRAPHY   ULTRA CENTRIFUGATION ELECTROPHORESIS          RH-00124
HUMAN ELECTROPHORESIS   ULTRACENTRIFUGATION  GUINEA PIGS# PO          RH-00063
ON-DAMAGED NUCLEIC ACID ULTRAVIOLET RAYS  DEOXYRIBONUCLEIC A          RH-00221
SOLUTIONS  ELECTRODES   ULTRAVIOLET RAYS  X RAYS SURFACE PRO          RH-00071
 CANCER  CHROMATOGRAPHY ULTRAVIOLET SPECTROMETRY# INACTIVATI          RH-00090
ROXIDES IN RADIOBIOLOGY UNSATURATED FATTY ACIDS  LIPID PEROX          RH-00238
M ON STREAM BIOTA BELOW URANIUM MILLS RADIOISOTOPES..RADIUM           RH-00077
ONS  X RAYS  COLCHICINE URETHAN  8 AZAGUANINE  6 MERCAPTOPUR          RH-00164
RATE CHELATING AGENTS   URINE  FECES  BLOOD..PLASMA  CALCIUM          RH-00222
ONDITIONING  BEHAVIOR   VAGOTOMY  NERVOUS SYSTEM  RATS ADREN          RH-00068
N ALGAE  FISH  SEASONAL VARIATIONS# EFFECTS OF RADIUM ON STRE          RH-00077
ATION EFFECTS ON DERMAL VASCULAR PERMEABILITY RADIATION EFFE          RH-00219
OLOGICAL EFFECTS OF LOW VELOCITY ELECTRONS# ELECTRICITY  BACT         RH-00204
VIRUSES..TOBACCO MOSAIC VIRUS  CHROMATOGRAPHY  HUMAN ELECTRO          RH-00063
CTIVITY  GAMMA GLOBULIN VIRUSES..TOBACCO MOSAIC VIRUS  CHROM          RH-00063
L STUDY  RATS..ALBINO   VISUAL PERCEPTION HEART RATE# BEHAVI          RH-00065
 PHOTOREACTIVATION  IN  VITRO# PHOTOENZYMIC REPAIR OF RADIAT          RH-00221
  CELL COMPONENTS..CELL WALL  INSTRUMENTATION RADIATION EFFE          RH-00204
M  RESINS..ION EXCHANGE WASTE TREATMENT  RADIATION PROTECTIO          RH-00029
E SHELLFISH RADIOACTIVE WASTES  CRUSTACEANS  MOLLUSKS  MONIT          RH-00074
 TUNICATES  RADIOACTIVE WASTES  MONITORING  OYSTERS# RADIOAC          RH-00073
NTAMINATION RADIOACTIVE WASTES  STRONTIUM  RESINS..ION EXCHA          RH-00029
ES..RADIUM  RADIOACTIVE WASTES  WATER POLLUTION ALGAE  FISH           RH-00077
M  RADIOACTIVE WASTES   WATER POLLUTION ALGAE  FISH  SEASONA          RH-00077
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 BACKGROUND RADIATION   WATER SAMPLING# BACKGROUND RADIATION        RH-00054
SOTOPES..STRONTIUM 90   WATER SUPPLY  ATMOSPHERE PLANTS  ECO        RH-00030
U  LICHENS MOSS  SOIL   WATER SUPPLY  ECOLOGY..ANIMAL# BIOAC        RH-00117
GY..HUMAN  ATMOSPHERE   WATER SUPPLY  SOIL FOOD CONTAMINATIO        RH-00054
ION OF RADIONUCLIDES IN WATER# COLLOID-SOLUTE SORBT                 RH-00183
N HAZARDS  INLAND FRESH WATERS  ECOLOGY..ANIMAL RADIOISOTOPE        RH-00215
UNUCLEIC ACID MOLECULAR WEIGHT  ADENOSINE PHOSPHATES  GLUTAT        RH-00089
WTH  BONE DENSITY  BONE WEIGHT  RATS LOCALIZED RADIATION  CH        RH-00094
     AUTORADIOGRAPHY OF WHOLE ANIMALS CONTAINING CARBON 14#         RH-00308
  RETENTION METABOLISM# WHOLE-BODY COUNTING OF RADIOACTIVITY        RH-00091
ION DURING DERMATOLOGIC X RAY THERAPY GONADS  RADIATION THER        RH-00258
.WHOLE BODY RADIATION   X RAYS  AGE  LUNG RADIATION SENSITIV        RH-00272
.WHOLE BODY RADIATION   X RAYS  AGE SKELETON  GROWTH  BONE D        RH-00094
RES RADIATION EFFECTS   X RAYS  CELL DIVISION..MITOSIS KB CE        RH-00035
HROMOSOMES  MUTATIONS   X RAYS  COLCHICINE URETHAN  8 AZAGUA        RH-00140
.WHOLE BODY RADIATION   X RAYS  CYSTAMINE RADIATION PROTECTI        RH-00067
S  RADIATION PROTECTION X RAYS  CYSTEAMINE  BEHAVIOR  MENTAL        RH-00306
 RADIATION PROTECTION   X RAYS  DENTAL PERSONNEL  HARTFORD G        RH-00260
 RADIATION PROTECTION   X RAYS  DENTISTRY..ORTHODONTICS RADI        RH-00113
 EFFECTS  FLUOROSCOPY   X RAYS  DOSAGE ELECTRONIC RECORDING         RH-00003
ION RADIATION EFFECTS   X RAYS  EMBRYO  INFANTS..ANIMALS NEO        RH-00081
RADIATION SENSITIVITY   X RAYS  FETUS  AGE  SEX DIFFERENCE C        RH-00097
RAT RADIATION EFFECTS   X RAYS  FETUS  LONGITUDINAL STUDY RA        RH-00086
RADIATION SENSITIVITY   X RAYS  INTESTINAL NEOPLASMS ADENOCA        RH-00021
AYS RADIATION EFFECTS   X RAYS  NEOPLASMS  THYMUS NEOPLASMS         RH-00210
ROMOSOME CHANGES IN MAN X RAYS  RADIATION EFFECTS  GENETICS.        RH-00024
REE ANIMALS GERM FREE   X RAYS  RADIATION EFFECTS  RADIATION        RH-00239
NOSTIC X-RAY PROCEDURES X RAYS  RADIOGRAPHY  DOSAGE  FLUOROS        RH-00085
DOSE IN X-RAY DIAGNOSIS X RAYS  RADIOGRAPHY  DOSAGE  INSTRUM        RH-00096
FECTS  MARINE BIOLOGY   X RAYS  RADIOISOTOPES ECOLOGY..ANIMA        RH-00076
 RADIATION PROTECTION   X RAYS  RIBONUCLEIC ACID MOLECULAR W        RH-00089
IATION EFFECTS  AGING   X RAYS  STRESS  ANGIOTENSIN ELECTROL        RH-00078
ENTATION  CALORIMETRY   X RAYS GAMMA RAYS# CALORIMETRIC MEAS        RH-00105
RADIATION SENSITIVITY   X RAYS RADIATION PROTECTION  GENETIC        RH-00294
DES  ULTRAVIOLET RAYS   X RAYS SURFACE PROPERTIES  IONIZING         RH-00206
IMETRIC MEASUREMENTS OF X- AND GAMMA RADIATION RADIATION THE        RH-00105
CRIMINATION LEARNING IN X-IRRADIATED RATS RADIATION EFFECTS.        RH-00067
MPATIBILITY# EFFECTS OF X-IRRADIATION ON THE SMALL INTESTINE        RH-00021
VIORAL EFFECTS OF FETAL X-IRRADIATION RADIATION EFFECTS  FET        RH-00065
OTHER SEQUELAE OF FETAL X-IRRADIATION RADIATION EFFECTS  X R        RH-00081
ILITY  MICE..CFI# FETAL X-IRRADIATION. DIFFERENTIATION AND F        RH-00097
ECTION AGAINST PRENATAL X-IRRADIATION# PROT                         RH-00080
KB CELLS  CELL CULTURE# X-RADIATION EFFECTS IN EUPLOID HUMAN        RH-00035
E  ANIMAL BIOCHEMISTRY# X-RADIATION PROTECTION BY CHEMICAL A        RH-00089
 TO SKELETAL EFFECTS OF X-RADIATION RADIATION EFFECTS..WHOLE        RH-00094
PHY  RABBITS# EFFECT OF X-RAY AND RADIOMIMETIC AGENTS ON LYM        RH-00293
EDUCING PATIENT DOSE IN X-RAY DIAGNOSIS X RAYS  RADIOGRAPHY         RH-00096
OLOGICAL APPLICATION OF X-RAY DOSIMETRIC DATA RADIOGRAPHY  R        RH-00092
AGENTS  CLINICAL STUDY# X-RAY INDUCED CHROMOSOME CHANGES IN         RH-00024
      MONKEYS# AGING IN X-RAY IRRADIATED AND NON-IRRADIATED         RH-00066
ESIGN CHANGES IN DENTAL X-RAY MACHINES RADIATION PROTECTION         RH-00113
RIBUTIONS IN DIAGNOSTIC X-RAY PROCEDURES X RAYS  RADIOGRAPHY        RH-00085
CHROMOSOMES AFTER SCALP X-RAYS AND IN GENODERMATOSES#               RH-00299
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F THE THRESHOLD DOSE OF X-RAYS# A STUDY O                           RH-00326
UNADS DURING DIAGNOSTIC XRAY RADIOGRAPHY  DIAGNOSTIC..TESTS         RH-00084
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IVE IRON, AFTER FIFTEEN YEARS RADIATION EFFECTS  RADIOLABELE        RH-00303
ING RADIOSENSITIVITY IN YEAST# BIOLOGICAL FACTORS AFFECT            RH-00312
ANCER BONE..NEOPLASMS   ZIRCONIUM CITRATE  CHELATING AGENTS         RH-00139
OSAGE  MICE# EFFECTS OF ZIRCONIUM CITRATE ON SR-89 BONE CANC        RH-00139
 SEROTININ  HISTAMINE   ZONE ELECTROPHORESIS COLUMN CHROMATO        RH-00203
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 RADIOISOTOPES..RHODIUM 106  RADIOISOTOPES..TECHNETIUM 99 RA        RH-00047
ADIOISOTOPES..RUTHENIUM 106 RADIOISOTOPES..RHODIUM 106  RADI        RH-00047
  RADIOISOTOPES..IODINE 131 RADIOISOTOPES..CESIUM 137  RADIO        RH-00173
7 RADIOISOTOPES..CESIUM 134  METHODOLOGY  RETENTION METABOLI        RH-00091
  RADIOISOTOPES..CESIUM 137  MILK  SOIL RADIOISOTOPES..STRON        RH-00030
1 RADIOISOTOPES..CESIUM 137  RADIOISOTOPES..STRONTIUM 90 MET        RH-00173
0 RADIOISOTOPES..CESIUM 137  STREAMS  RETENTION  TUBIFEX# AC        RH-00215
  RADIOISOTOPES..CESIUM 137 RADIOISOTOPES..CESIUM 134  METHO        RH-00091
S RADIOISOTOPES..CARBON 14  RADIATION EFFECTS  GONADS CELL D        RH-00243
IMALS CONTAINING CARBON 14# AUTORADIOGRAPHY OF WHOLE AN             RH-00303
D REACTION MECHANISMS   2 MERCAPTOETHANOL# MERCAPTO-DISULFID        RH-00305
RADIOISOTOPES..THALLIUM 204  RADIOISOTOPES..PHOSPHORUS 32 RA        RH-00047
ADIOISOTOPES..PLUTONIUM 229 RADIOAUTOGRAPHY  RATS# OCCUPATIO        RH-00047
 RADIOISOTOPES..SILICON 31 RADIOISOTOPES..COPPER 64  RADIOIS        RH-00215
DIOISOTOPES..PHOSPHORUS 32  RADIOISOTOPES..SILICON 31 RADIOI        RH-00215
DIOISOTOPES..PHOSPHORUS 32 RADIOISOTOPES..YTTRIUM 90  RADIOI        RH-00047
 TRITIUM  BONE MARROW   5 IODODEOXYURIDINE CATARACT  MICE  E        RH-00099
URETHAN  8 AZAGUANINE   6 MERCAPTOPURINE  SPERMATOGENESIS DR        RH-00140
A RADIOISOTOPES..COBALT 60  MORTALITY  RADIATION PROTECTION         RH-00257
S RADIOISOTOPES..COBALT 60  SKIN  BLOOD CELLS CANCER CHEMOTH        RH-00024
1 RADIOISOTOPES..COPPER 64  RADIOISOTOPES..STRONTIUM 90 RADI        RH-00215
TY  RADIOISOTOPES..ZINC 65# BIOCHEMICAL STUDIES ON ENDOCRINE        RH-00014
S  COLCHICINE URETHAN   8 AZAGUANINE  6 MERCAPTOPURINE  SPER        RH-00140
ADIOISOTOPES..STRONTIUM 85  MAGNESIUM  SODIUM SULFATE ADRENA        RH-00222
ADIOISOTOPES..STRONTIUM 89  RADIOISOTOPES..STRONTIUM 90 ACET        RH-00139
ADIOISOTOPES..STRONTIUM 90  BONE RADIOLABELED CALCIUM  RADIO        RH-00091
ADIOISOTOPES..STRONTIUM 90  CHELATING AGENTS  MUSCLE BONE NE        RH-00090
ADIOISOTOPES..STRONTIUM 90  DENTAL STRUCTURE..TEETH CHILDREN        RH-00112
ADIOISOTOPES..STRONTIUM 90  LICHENS MOSS  SOIL  WATER SUPPLY        RH-00117
RADIOISOTOPES STRONTIUM 90  MONITORING# SR-90 IN DECIDUOUS T        RH-00252
 RADIOISOTOPES..YTTRIUM 90  RADIOISOTOPES..PLUTONIUM 229 RAD        RH-00047
ADIOISOTOPES..STRONTIUM 90  WATER SUPPLY  ATMOSPHERE PLANTS         RH-00030
ADIOISOTOPES..STRONTIUM 90 ACETAZOLAMIDE  RADIATION PROTECTI        RH-00139
           ETH# STRONTIUM 90 EFFECTS ON PULP AND DEVELOPING TE      RH-00343
ADIOISOTOPES..STRONTIUM 90 METHODOLOGY# EFFECT OF FOOD PROCE        RH-00173
ADIOISOTOPES..STRONTIUM 90 RADIOISOTOPES..CESIUM 137  STREAM        RH-00215
DIOISOTOPES..TECHNETIUM 99 RADIOISOTOPES..THALLIUM 204  RADI        RH-00047
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DIVISION OF RADIOLOGICAL HEALTH

PHS RESEARCH GRANTS ACTIVE OCTOBER 1, 1964

SUMMARY BY GEOGRAPHIC AREA

STATE - COUNTRY	NO.	AMOUNT	STATE - COUNTRY	NO.	AMOUNT
Arkansas	2	$ 34,235	New Mexico	1	$ 14,020
California	5	128,406	New York	16	505,316
Colorado	2	63,506	North Carolina	1	20,565
Connecticut	1	2,590	Ohio	4	62,151
District of Columbia	1	16,172	Oklahoma	1	16,278
Florida	2	68,154	Oregon	1	20,508
Georgia	8	136,154	Pennsylvania	6	116,065
Illinois	7	116,765	Tennessee	3	49,236
Indiana	4	73,786	Texas	3	68,167
Iowa	2	16,122	Utah	3	116,332
Kansas	2	29,610	Virginia	2	16,336
Kentucky	1	3,420	Washington	1	61,974
Louisiana	1	38,512			
Maryland	4	119,179	England	1	35,725
Massachusetts	9	206,976	Finland	1	45,000
Michigan	4	51,845	Italy	1	7,500
Minnesota	1	22,093	Japan	3	30,862
Mississippi	1	8,082	Norway	1	17,350
Missouri	4	77,329	Portugal	1	13,983
			Sweden	2	15,900

TOTALS: 38 States and Countries - 113 Grants - $2,446,204

Research Grants Staff
Division of Radiological Health
Bureau of State Services (E
Public Health Service
October 15, 1964

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DIVISION OF RADIOLOGICAL HEALTH

LISTING BY GEOGRAPHIC AREA AND GRANTEE INSTITUTION

BUREAU OF STATE SERVICE - ENVIRONMENTAL HEALTH

ACTIVE OCTOBER 1, 1964

ARKANSAS

Little Rock

University of Arkansas Medical Center

Lohmann, Wolfgang H.	Radiation and Protection in Enzyme Systems	RH 00197-01	$10,000-64
Young, Ellen A.	Effect of Radiation on Amino Acid Transport	RH 00334-01	$24,235-65

CALIFORNIA

Berkeley

University of California

Calloway, Doris H.	Characterization of Radioprotective Factor in Alfalfa	RH 00373-01	$30,052-65

Long Beach

Long Beach State College Foundation, Inc.

Garcia, John	Physiological Basis of Radiation-Conditioned Behavior	RH 00068-04	$30,188-65

Los Angeles

California College of Medicine

Finkle, Raymond D.	Autoradiography of Whole Animals Containing Carbon-14	RH 00308-01	$13,548-64

Univ. of Southern California

Haymond, Herman R.	Radiation Effects on Formation of Protein Aggregates	RH 00005-04	$22,860-65

CALIFORNIA (Continued)

Menlo Park

Stanford Research Institute Calloway, Doris H.	Characterization of Radioprotective Factor in Alfalfa	RH 00257-01	$31,758-63

COLORADO

Fort Collins

Colorado State University Gowen, John W.	Ancestral vs Direct Effects of Irradiation on Mammals	RH 00328-01	$57,916-64
Sloan, Kenneth W.	Effects of Irradiation of the Exteriorized Rat Kidney	RH 00336-01	$ 5,590-64

CONNECTICUT

Hartford

Hartford Health Department Menczer, Leonard F.	Level of Dental Radiation Hygiene In Community	RH 00260-01	$ 2,590-63

DISTRICT OF COLUMBIA

Washington, D. C.

Georgetown University Brayer, Franklin T.	A Study of The Threshold Dose of X-Rays	RH 00326-01	$16,172-64

FLORIDA

Jacksonville

Florida State Board of Health			
Roessler, Charles E.	Radionuclides in Florida Milk	RH 00175-01	$30,000-64
Williams, Edwin G.	Background Radiation in Florida	RH 00054-02	$38,154-64

GEORGIA

Athens

University of Georgia			
Caster, William C.	Biological Mechnisms of Radiation Damage	RH 00367-01	$16,960-64
Johnston, Francis J.	Radiation Effects in Heterogeneous Systems	RH 00206-03	$10,447-65
Plummer, Gayther L.	Bioaccumulation of Radionuclides in Granite Ecosystems	RH 00117-03	$13,859-64
Sax, Karl	Cytological Analysis of Aging in Plant Cells	RH 00294-01	$ 4,002-64

Atlanta

Emory University			
Rohrer, Robert H.	Photoconductive Absorbed Radiation Dosimetry	RH 00159-01	$12,521-64
Weens, H. Stephen	Absorbed Radiation Dose in Fluoroscopic Procedures	RH 00003-05	$26,948-63
Weens, H. Stephen	Critical Organ Exposure During Fluroscopy	RH 00357-01	$35,070-65
Georgia Institute of Technology			
Fetner, Robert H.	X-Radiation Effects in Euploid Human Cell Cultures	RH 00035-04	$16,347-65

Chicago

University of Chicago			
Goepp, Robert A.	Local Chemical Radiation Protection in Mice	RH 00268-02	$15,783-65
Griem, Melvin L.	Analysis of Children Radiated Early in Fetal Life	RH 00207-02	$10,339-64
Malkinson, Frederick D.	Effects of Drugs and Radiation on Hair and Hair Growth	RH 00280-02	$16,310-65
University of Illinois			
Coviello, Dominick A.	α-Alkyloximinomercaptans for Protection in Radiotherapy	RH 00293-01	$11,023-64
Loyola University			
Remenchik, Alexander P.	Accuracy of Assay by Body Counters of K-40 in Man	RH 00283-02 RH 00283-02S1	$12,000-65 $ 8,712-65
Spencer, Herta	Studies of Radiostrontium Metabolism and Removal in Man	RH 00222-02	$39,217-64

DeKalb

Northern Illinois University			
Mittler, Sidney	Antimitotic Chemicals As Protection Against Radiation	RH 00140-01	$ 3,381-64

INDIANA

Lafayette

Purdue Research Foundation			
Davis, Robert E.	Anti-Radiation Drugs	RH 00279-02	$ 9,114-65
Christian, John E.	Altered Metabolism Studies of I-131 and Sr-90	RH 00211-01	$24,783-64
Goodnight, Clarence J.	Accumulation and Retention of Radionuclides by [illegible]	RH 00215-02	$11,320-64

INDIANA

Notre Dame

University of Notre Dame Wilson, Raphael	Radiation Protection and Recovery in Germfree Animals	RH 00239-02	$28,569-64

IOWA

Iowa City

University of Iowa Osborne, James W.	Effects of X-Irradiation on the Small Intestine	RH 00021-11	$10,722-65
Witiak, Donald T.	Aminothioimides as Radiation-protective Agents	RH 00324-01	$ 5,400-64

KANSAS

Lawrence

University of Kansas Leone, Charles A.	Potentiation of Antigens by Gamma-ray Irradiation	RH 00063-07	$16,599-65

Manhattan

Kansas State University Searles, Scott, Jr.	Alpha-Amino Mercaptans and Alpha-Amino Sulfides	RH 00300-01	$13,011-64

KENTUCKY

Lexington

University of Kentucky Smith, Walter T. Jr.	Mechanism of Thiol Protection Against Radiation	RH 00193-02	$ 3,420-65

LOUISIANA

New Orleans

Loyola University Jolley, Homer R.	Sr-90 in Deciduous Teeth in the Gulf Coast Area	RH 00252-02	$38,512-64

MARYLAND

Baltimore

Johns Hopkins University Morgan, Russell H.	Dose Distributions in Diagnostic X-Ray Procedures	RH 00085-08	$74,838-65
Morgan, Russell H.	Epidemiological Application of X-Ray Dosimetric Data	RH 00092-03	$14,310-63
Rupert, Claud S.	Photoenzymic Repair of Radiation-Damaged Nucleic Acid	RH 00221-03	$10,380-65
Seltser, Raymond R.	A Study of Survivorship and Mortality of Radiologists	RH 00075-05	$19,651-64

MASSACHUSETTS

Boston

Harvard University School of Public Health Shapiro, Jacob	Distribution of Radioactive Particles in Enclosures	RH 00276-01	$19,376-64
Massachusetts College of Pharmacy Foye, William O.	Radioprotective Basic Thiols	RH 00297-01	$18,456-64
Northeastern University Weiss, Karl	Laser Radiation in Photochemistry	RH 00302-01	$14,053-64

MASSACHUSETTS

Boston

New England Deaconess Hospital			
Joftes, David L.	Effect of C-14 on Cytogenetics	RH 00243-02	$31,020-64
Tufts University			
Wagner, Richard	X-Radiation Protection by Chemical Agents in Guinea Pigs	RH 00089-04	$12,276-65

Cambridge

Massachusetts Institute of Technology			
Goldblith, Samuel A.	Improvement in Sanitation By Ionizing Radiation	RH 00061-09	$31,801-64

Shrewsbury

Worcester Foundation for Experimental Biology			
Chang, M. C.	Effects of Ionizing Radiation on Mammalian Gametes and Zygotes	RH 00309-01	$25,044-64

Woods Hole

Marine Biological Laboratory			
Armstrong, Philip B.	Radiobiological Research on Marine Organisms	RH 00076-06	$24,500-65

Worcester

Clark University			
Anderson, Roy S.	Studies of Radiation Damage to Biological Materials	RH 00008-04	$30,450-65

MICHIGAN

Ann Arbor

University of Michigan			
Burns, Charles H.	Reduced-Flavin Oxidation in Primary Radiation Damage	RH 00245-02	$10,065-64

Ann Arbor			
University of Michigan			
King, John S.	Measurement of Neutron Spectra in Biological Shields	RH 00253-01	$18,937-64
Richards, Albert G.	A Study of Design Changes in Dental X-Ray Machines	RH 00113-05	$ 4,668-65
Detroit			
Wayne State University			
Havlena, Joan M.	Cysteamine and X-Rays Prenatally, Behavior of the Rat	RH 00306-01	$18,175-64
MINNESOTA			
Austin			
University of Minnesota			
Chipault, Jacques R.	Effects of High Energy Radiations on Lipids	RH 00358-01	$22,093-65
MISSISSIPPI			
University of Mississippi			
Haining, Joseph L.	Fatty Acid Hydroperoxides in Radiobiology	RH 00238-02	$ 8,082-64
MISSOURI			
Columbia			
University of Missouri			
Hemphill, Louis	Radioactivity in Bottom Sediments	RH 00369-01	$18,370-64
Kuntz, Robert R.	Studies in Radiation Protection	RH 00321-01	$10,034-64
McQuade, Henry	Radiation Effects of Thymidine-Tritium	RH 00347-07	$18,953-65

MISSOURI

St. Louis

Washington University Bird, John T.	To Study Radioactive Nuclides in Teeth and Bone	RH 00112-05	$29,972-64

NEW MEXICO

Albuquerque

Lovelace Foundation for Medical Education and Research Howarth, John L.	Digital Computing Techniques in Radiological Problems	RH 00286-01	$14,020-64

NEW YORK

Brooklyn

Brooklyn College Beam, Carl A.	Biological Factors Affecting Radiosensitivity in Yeast	RH 00312-02	$10,713-65

Buffalo

Health Research, Inc. Ambrus, Clara M.	Autologous Bone Marrow Protection and Chemotherapy	RH 00026-06	$13,328-64

Mt. Vernon

Consumers Union of U.S., Inc. Michelson, Irving	Radioisotopes in the Total Diet	RH 00342-01	$27,860-64

New York City

Columbia University Rossi, Harald H.	RBE of Monoenergetic Neutrons	RH 00099-04	$25,494-65
Rugh, Roberts	Aging & Other Sequelae of Fetal X-Irradiation	RH 00081-04	$28,039-64
Rugh, Roberts	Fetal X-Irradiation, Differentiation and Fertility	RH 00097-05	$26,218-64

New York City

Hunter College			
Green, Morris	Protein Metabolism in Normal & Irradiated Lenses	RH 00345-01	$ 7,672-64
Manhattan College			
Malsky, Stanley J.	Thermoluminescent Dosimetry(Phantom and Human Systems)	RH 00137-02	$23,400-64
New York U. Medical Center			
Albert, Roy E.	Follow-Up Study of Irradiated Tinea Capitis Cases	RH 00298-01	$96,557-64
Kushner, Marvin	Occupational Lung Cancer from Ionizing Radiation	RH 00047-06	$70,035-64
Morrill, Donia D.	Chromosomes after Scalp X-rays and in Genodermatoses	RH 00299-01	$25,128-64
Slobodian, Evelyn	Inactivation of Enzymes by Ionizing Radiation	RH 00095-06	$32,440-65
Sloan Kettering Institute for Cancer Research			
Epp, Edward R.	Reactive Lifetime Studies in Irradiated Cells	RH 00340-01	$31,489-64

Rochester

Eastman Dental Dispensary			
Guzma, Cesar A.	Strontium 90 Effects on Pulp and Developing Teeth	RH 00343-01	$11,476-64
University of Rochester			
Hempelmann, Louis H.	Neoplasms in Children Treated with X-Rays	RH 00210-02	$49,902-64
Strain, William H.	Compounds to Promote Excretion of Radioisotopes	RH 0004[illegible]-03	$25,565-64

NORTH CAROLINA

Davidson

Davidson College			
Lammers, William T.	Colloid-Solute Sorbtion of Radionuclides in Water	RH 00183-01	$20,565-64

OHIO

Cincinnati

University of Cincinnati Goldman, Leon	X-Ray Induced Chromosome Changes in Man	RH 00024-04	$24,284-65
Institutum Divi Thomae Sperti, George S.	Biological Effects of Low Velocity Electrons	RH 00204-02	$ 6,000-64

Columbus

Ohio State University Geisman, Jean R.	Effect of Food Processing on Radioactive Fallout	RH 00173-03	$19,417-65

Wooster

Ohio State University Franklin, Ralph E.	Fission Product - Soil Organic Matter Complexes	RH 00124-03	$12,450-64

OKLAHOMA

Stillwater

Oklahoma State University Gorin, George	Mercapto-Disulfide Interchange in Radioprotection	RH 00305-01	$16,278-64

OREGON

Corvallis

Oregon State University Conte, Frank P.	Effects of Radiation on the Migration of Salmonids	RH 00246-01	$20,508-64

PENNSYLVANIA

Lancaster

Franklin and Marshall College Weller, Richard J.	Environmental Radioactivity	RH 00366-03	$15,400-64

Philadelphia

Albert Einstein Medical Center Schwartz, Emanuel	Protection Against Radiation Effects on Renal Function	RH 00319-01	$21,526-65
Tabachnick, Joseph	Beta Irradiation Effects on Dermal Vascular Permeability	RH 00218-02	$31,304-64
Philadelphia General Hospital [illegible]ber, William	Clinical Dosimetry for Cobalt-60 Therapy	RH 00045-01	$13,724-64
Temple University Forbes, P. Donald	Effects of Aging and Radiation on Haarscheibe Pigment	RH 00163-01	$14,857-64

Pittsburgh

University of Pittsburgh Shapiro, Maurice A.	Sorption of Heavy Metal Radionuclides by Minerals	RH 00322-01	$19,254-64

TENNESSEE

Knoxville

University of Tennessee Furchtgott, Ernest	Behavioral Effects of Fetal X-Irradiation	RH 00065-10	$15,292-65

Nashville

Vanderbilt University Bouldin, Walter V.	ESR Studies of Radiation Damage in Bio-Materials	RH 00288-01	$13,836-64
Heyssel, Robert M.	Prenatal Exposure to Radioactive Iron: After 15 Years	RH 00303-01	$20,108-64

TEXAS			
College Station			
Texas A&M Research Foundation Hupp, Eugene W.	Low Level Gamma Radiation and Physiological Performance	RH 00330-01	$29,872-65
Texas A&M University Creger, Clarence R.	The Metabolism of Radistrontium	RH 00354-01	$23,757-65
Galveston			
University of Texas Schneider, Martin	Effects of Irradiation on Aging of Small Animals	RH 00078-04	$14,538-63
UTAH			
Logan			
Utah State University Sigler, William F.	Effects of Radium on Stream Biota Below Uranium Mills	RH 00077-05	$18,681-64
Salt Lake City			
University of Utah Burdette, Walter J.	Alterations of Genetic Replication	RH 00116-02	$16,632-64
Pendleton, Robert C.	Environmental Effects on the Content of Cs^{137} in Milk	RH 00030-03	$81,019-64
VIRGINIA			
Charlottesville			
University of Virginia Speidel, Carl C.	Differential Resistance of Cells to Irradiation	RH 00325-01	$ 4,272-64
Richmond			
Medical College of Virginia Wooles, Wallace B.	Genesis of Postirradiation Hyperlipemia	RH 00318-01	$12,064-64

WASHINGTON

Seattle

University of Washington Thomas, E. D.	Irradiation and Marrow Transplantation in Large Animals	RH 00311-02	$61,974-65

FOREIGN GRANTS

ENGLAND

London

University of London Rotblat, Joseph	The Age Factor in Radiation Sensitivity of Mammals	RH 00272-01	$35,725-64

FINLAND

Helsinki

University of Helsink Miettinen, Jorma K.	Biological (enrichment) Chains of Radionuclides in Finnish Lakes	RH 00307-01	$45,000-64

ITALY

Rome

Comitato Nazionale Energia Nucleare Monesi, Valerio	Cell Division Cycle and Radiosensitivity - Metabolic Studies	RH 00304-01	$ 7,500-64

JAPAN

Chiba

National Institute of Radiological Sciences

Tamaoki, Bun-ichi	Biochemical Studies on Endocrine System under Radiation	RH 00014-03	$ 6,086-64

Okayama

Okayama University

Mochizuki, Yohio	Natural Radioactivity in Humans and Their Environment	RH 00316-01	$19,964-64

Sizuoka-ken

National Institute of Genetics

Hiraizumi, Yuichiro	Effect of Radiation-Induced Mutations on Fitness	RH 00034-03	$ 4,812-64

NORWAY

Montebello

Norsk Hydro's Institute for Cancer Research

Pihl, Alexander	Enzymatic and ESR Studies of Radiation Damage	RH 00098-05	$17,350-65

PORTUGAL

Lisboa

University of Lisboa

da Silva Horta, Jorge	Research on the Effect of Thorotrast	RH 000039-04	$13,983-64

SWEDEN

Lund

University of Lund Liden, Kurt V. H.	Whole Body Counting of Radioactivity in Humans	RH 00091-03	$ 9,900-63

Stockholm

University of Stockholm de Hevesy,George	Radiosensitivity of Extramedullar Erythropoiesis	RH 00166-03	$ 6,000-65